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# Maintenance Welding and Cutting Operations on Radioactive Equipment

By E. B. LAVELLE and J. M. FOX, JR. (From *The Welding Journal, U.S.A.*, Vol. 34, No. 8, August 1955, pp. 731-740, 10 illustrations.)

*With proper consideration of the hazards involved, conditions of working with radioactive materials can be made as safe as those in any industry, provided that there is proper planning, coupled with adequate training of personnel and competent supervision.*

THE contamination of process equipment ordinarily results from the deposit or attachment of finely divided radioactive substances on the surface of the metallic material. The degree of radiation emitted by these particles may range from insignificant to that which effectively prevents handling, except by remote methods where the operator is shielded by lead, concrete, water, or comparatively great distances. Because of the nature of the equipment, removal of these contaminating substances may be very difficult, and may be impossible in a substantial number of instances. A further complication is that the metallic material of which the equipment is fabricated may itself become radioactive after long exposure to intense neutron radiation. The radioactive life of the deposited material may range from several seconds to thousands of years. It is possible in certain instances to set the equipment aside and permit the radioactivity to decay to a level which permits practical working time limits, or else to render the equipment suitable for standard decontamination methods for removal of the contaminating material. Ordinarily, the course of action is decided when the level of radioactivity is determined for the specific item of equipment.

In certain instances when the unit is extremely radioactive and cannot be decontaminated to the extent that welding or cutting operations are possible, it must be replaced. Spare equipment can be provided for this purpose. The operation of replacing certain process equipment is very costly and time-consuming, and it would be very helpful if contact maintenance could be performed on all such units. With some, however, the level of radioactivity is so high that attempts to decontaminate to a workable level would be futile. There is no way of avoiding disposal of such equipment. Considering that certain replacement operations are done by remote means with the operator observing the equipment through a periscope or mirror, the difficulty of overcoming unforeseen occurrences can be understood.

## RADIATION SURVEY

No maintenance operation should be considered without an adequate survey for radiation in the work area. It is anticipated that, as further information is developed, even more effective protective measures can be used and can thus extend the working period for personnel exposed to radiation of the various kinds.

A radiation survey of a work area involves a thorough search for radioactive material. This is carried out with various electronic instruments provided for that purpose. The location and intensity of radiation are made a matter of record. This permits maintenance personnel to determine whether it is practical to attempt decontamination of the job area and repair of the specific item, or whether replacement is indicated. A radiation survey may also establish that certain equipment is abnormally subject to contamination and that subsequent design changes are indicated for similar equipment. The physical operation of surveying a work area for harmful radiation is simple, but requires painstaking effort by a highly skilled radiological technician.

## MAINTENANCE PRACTICES

All facets of normal industrial procedures are affected by radioactivity, but none, perhaps, as greatly as maintenance practices. Proper maintenance has always been a subject of much concern and study. In the atomic-energy field, the impact of radioactivity upon maintenance has been enormous.

Within the maintenance framework, cutting and welding are essential tools, and even in atomic installations have not changed very much in the essentials of equipment or operation. The way in and the conditions under which they are used single out cutting and welding for attention. At first blush, it would appear that the operations are standard, the equipment is standard, and the results are standard. These are familiar and are not hard to visualize; it is the new factor of radioactive contamination or the presence of radiation that creates a difference—the reason why, for example, even though a weld bead may need only 1 in. more to be complete, the weld must be stopped and a new welder must complete the job.

Under normal conditions of plant maintenance in industries other than those concerned with the processing of radioactive materials, maintenance procedures have become fairly standardized through continued repetition work, in which welding and cutting operations have, for many years, been indispensable. However, with the necessity for maintenance work to be performed on radioactive process equipment, a new and important factor has to be introduced into the cost calculations. Now, rather than the workman approaching the work area at random or at his will, all operations, even the most simple, must be completely organized. The condition of radioactivity and of unseen danger has posed a problem which has had to be approached with extreme care until considerable information could be accumulated. Now that some of the facts are known and have been recognized, it is possible for personnel to work under conditions of radiation in comparative safety.

## CONTROL OF OPERATIONS

Complete control of every phase of the maintenance operation must be maintained. Nothing can be left to chance or dependence upon the trade knowledge of the individual welder or mechanic that a certain specific operation will be done. All phases and details of the operation must be listed, analysed, and considered in relation to the overall job. Not the least of these is the radiation survey which precedes, continues during, and completes each job.

A supervisor, known as a "radiation monitor," measures the amount of radiation each worker receives when in an area of possible exposure. Every person entering a controlled area carries small ionization chambers and a film badge. The ionization chambers are read and recorded daily. The film badges are developed every two weeks. These readings are recorded in such a manner as to provide cumulative statistics which assist in determining the effectiveness of the radiation protection programme.

When the nature of the work is such that radiation laboratories cannot be provided, the health physicist must satisfy himself that special ventilation and similar devices will remove dangerous welding fumes to such a low level of concentration in the air that the workers in the area cannot inhale unsafe quantities. Periodic tests are made on each worker in radioactive areas to determine if any radioactive material has been deposited in the body.

Beta-gamma-sensitive and alpha-sensitive instruments are installed at convenient locations, so that each worker can be measured for contamination of hands, feet, body, clothing, and equipment. These checks are mandatory upon leaving a controlled area.

Emergency procedures have been developed at all installations. Specialists are prepared to cope with any unusual occurrence in the case of emission of significant amounts of radioactive contaminants from reactors or chemical plants. A great deal of research is being done to determine the toxicity of the various radioactive materials and ways in which a person contaminated with them can be successfully treated.

The greatest cause of personnel contamination results from improperly or carelessly worn protective clothing. In a radiation zone where maintenance work is accomplished, care must be exercised to enforce regulations. Two suits of coveralls, taped-on shoe covers, taped-on rubber gloves, and a breathing mask can be uncomfortable and hot. Ordinarily, if a workman's clothing has become disarranged in such a manner that he may become contaminated, the radiation monitor will call it to his attention. If a survey should indicate that the workman has become contaminated, he would immediately be taken from the work area. The radiation monitor is ever on the alert for any changes in the radiation level in the work area and will immediately notify the workmen of any change of which they should be made aware.

An important part of the duties of a radiation monitor is the survey of a contaminated area, to determine the maximum permissible time a welder can operate. The information he will record is the exposure time permissible and the distance to be observed. Both of these readings are very important, as the mechanic or welder must know how long he can work in the area and how close he can get to the work. Whether or not he forgets this vital information is immaterial, as the timekeeper will inform him when he has reached his exposure limit, at which time he will immediately leave the work area.

If the radiation level in the work area is high, ordinarily the radiation monitor will determine the work interval at the job itself, and then designate an area where the radiation is lower, so that the workmen can step out of the work area and into the zone of lower radiation where they may pass tools, relay information, or stand by in case of need. This, then, extends the time which they can assign to the work itself, and without danger to themselves. For example, and to show how important it is that the work area be adequately monitored and surveyed for radiation, one process vessel which was removed from service indicated at a distance of 125 ft a permissible working time of 26 sec. At a distance of 65 ft, the time limit was reduced to 4 sec. Normally, when the initial radiation is so intense, it is not practical to attempt to decontaminate the equipment down to radiation levels where effective work can be done.

When considering welding operations, it is more difficult to do a welding or cutting job at a distance of several feet than it is at a distance of, say, 6 in. This is taken into consideration when setting up exposure time limits for certain welding operations.

### Typical Maintenance Operations

A typical sequence of operations for a welding maintenance job would be as follows :—

(1) A failure in a radioactive process line occurs and a replacement must be welded in.

(2) A survey of the work area is made by a radiation monitor who establishes the work time limits at certain distances from the work.

(3) A decision is made as to which protective clothing must be worn, so as best to protect individual workmen. As an example of what may be required, all personal clothing may have to be removed and replaced by (*a*) one pair of coveralls, (*b*) one pair of shoe covers, (*c*) one pair of surgical gloves, taped to the sleeves of the coveralls, (*d*) one cape type of hood, tucked underneath, (*e*) another pair of coveralls, taped to (*f*) rubber boots, (*g*) leather gloves, and (*h*) a fresh-air or filtration type of mask, the type depending on the degree and kind of contamination present in the work area.

(4) The job is duplicated by a mock-up and the personnel who will do the job are required to rehearse the operation until all details are thoroughly understood.

(5) Meteorological conditions affect the work of bridge builders, linemen, etc. For certain field work on atomic installations, it is necessary to discontinue work if the wind suddenly rises in intensity, in order to prevent spread of contamination.

(6) The work area and the equipment to be replaced are decontaminated, where possible, to extend time limits.

(7) The defective pipe is removed and prepared for the replacement weld. This may involve portable exhaust hoods and filters, to lessen the possibility of airborne contamination from fumes.

(8) Welding equipment is checked.

(9) The job starts and continues until the welder reaches his time limit.

(10) The welder is stopped when his time limit is reached. He is required to leave the work area, whether or not the job is completed.

(11) The welder leaving the job reports conditions as they exist to the next welder on the schedule and makes his recommendations for continuing.

(12) The next welder on the work-assignment schedule continues his job.

(13) This procedure continues until the welding job is completed.

(14) The weld is inspected and tested.

(15) The work area is cleaned up and re-surveyed, to ascertain that all excess radioactive material which has resulted from the maintenance operation has been removed.

(16) The equipment is put back into service.

(17) The individual workmen are surveyed for radioactive contamination as they leave the job. The special clothing which they wore on the job is sent to a special laundry facility. If unusual contamination of the welder or mechanic has resulted from the operation, every effort is made to determine what actually happened, so that better protective procedures can be developed.

(18) Certain equipment used on the job is decontaminated, if possible or practical. Otherwise, it may be kept in controlled zones until the next similar job is encountered.

As a special precaution, it is customary to establish a roped-off area and to place radiation-zone signs where

work is to be done on radioactive process equipment. This serves the dual purpose of preventing unprotected personnel from entering the area and also makes the workmen engaged on the job more conscious of the radiation around them.

Also, if it is necessary to remove equipment from the location for a more thorough decontamination than could be performed there, a plastic vinylite sheeting or bag is sometimes used to cover the material or unit completely, in order that the spread of contamination can be more fully controlled.

### Planning Operations

When maintenance work is urgently required and the time limit is short (limited to a few minutes in certain instances), it is necessary to provide a number of stand-by mechanics and/or welders to carry on after the man working has exceeded his time limit. If the work is of considerable extent, it will be readily seen that the labour cost for such operations would be regarded as excessive under normal industrial maintenance conditions. When work of such nature must be done, the workmen are generally organized in groups and briefed so that better co-operation can be obtained. It should be obvious that, when such large crews are required, other maintenance operations are affected because of the need for withdrawing personnel from other locations or plants. Under such conditions, a number of people may receive their daily or weekly permissible radiation exposure. The workmen, having received their permissible exposure, must work in non-radioactive zones for the rest of the week. Thus, planning and scheduling the work become of the utmost importance.

To expedite certain work, it has been necessary to decontaminate partially certain items of equipment, and then, by means of long electrode holders using cutting electrodes or long cutting torches, to remove certain vital or difficult-to-replace components from the equipment. These removed sections are ordinarily small enough to be successfully decontaminated and can then be used to refabricate a spare item of equipment. Removal of such sections is usually critical as to time limits, and every effort is extended to assist the welder to accomplish as much as possible within the short work interval allotted him. A misunderstanding or error in judgment at such a time may seriously interfere with the pre-planned sequence of operations.

Very often the ground or floor, or equipment underneath the welding operation, will be covered with protective material which can be removed later. This avoids additional contamination of surrounding material or equipment.

After all work is completed and all debris is removed and taken away for disposal, the radiation monitor will make a final survey of the area. The special radiation signs can then be taken down and the ropes removed from the work area, signifying that the condition is again normal.

In the case of remote maintenance jobs, periscopes and mirrors are commonly used, but have not proved particularly successful in welding and cutting operations in the field. It is believed that much development work should be done in this connection and that it will eventually be practical to weld and cut by remote means.

### Welding and Cutting Procedures

Standard welding and cutting procedures can be used when working under radiation controls. The only difference is that local conditions may make it necessary that extensions must sometimes be used on cutting-torch or electrode holders or inert-arc torches. Also, greater attention must be given to absolute precision of technique and procedure, as the schedule may not tolerate a failure to make a satisfactory weld. Such an occurrence might adversely affect production schedules and have any number of repercussions later on.

Some consideration must be given to preventing the slag from the cutting operations going outside the work area. These operations are ordinarily performed on stainless steel, so that it is customary to use cutting electrodes, flux-injection, or iron-powder cutting for such work. It is not necessary to use exhaust units when the inert-arc process is employed but, in certain locations, the other processes require that the fumes be collected and passed through a disposable filter.

### Protective Clothing and Equipment

Welding clothing is not too comfortable at best, and it is now necessary to add in addition other equipment and clothing in order to safeguard the welder against contamination. It is believed that improvements could be made in this direction. Equipment manufacturers might possibly develop clothing which would better serve the triple purpose of protecting the wearer against thermal radiation, hot metal from the welding operation, and radiation from the equipment on which the work is being done. At present, the welder must wear the normal protective clothing used by all persons in a contaminated area and, in addition, leather gloves, jackets, and coveralls, if he is using a welding or cutting process which expels molten metal from the weld area itself. It might be possible to provide some garment which would offer adequate protection against these conditions.

The type of mask worn is governed by the kind of particulate matter and not by the level of radiation. Assault masks, self-contained breathing apparatus, and fresh-air masks are worn, the choice depending upon the work to be done. The fresh-air masks may be serviced from cylinders, or by fresh-air lines from outside the work area.

Oxy-acetylene cutting and welding equipment now available is, in the main, satisfactory, with the exception that more readily operable valves would be helpful. When the welder must wear a pair of rubber gloves, plus leather gloves, the manipulation of small valve heads or handles becomes rather difficult.

Welding equipment should be developed which is directed towards this specific type of maintenance welding operation. Welding hoods which could be removed without interfering with the breathing equipment would be helpful. Conventional equipment, it is believed, could be redesigned for greater comfort. For certain purposes, it is convenient to have breathing equipment and welding filter-lens holding apparatus combined, but it is believed that a greater variety of combinations of such devices should be provided, so that the welder can be at greater ease while he is engaged in the welding or cutting operation and as he is standing by while the mechanics are aligning the work or otherwise engaged. Portable fume-exhaust equipment which could itself be easily decontaminated would be very helpful. It is essential that welding fumes from radioactive equipment be controlled, as the air-borne particles may carry contamination to other equipment or contaminate the workers themselves. In certain instances, only one attempt may be made to repair the failed unit.

Although certain devices are available for the remote control of arc-welding generators, it is believed that such devices could be developed which would be more suitable for working under radiation control conditions. As welding technology increases, remote-control methods will undoubtedly be developed; at the moment, however, such methods are usable only in the laboratory. Present practice depends mostly on signals relayed between welder and helper to change welding-machine settings. This is irritating and time-consuming. However, unless remote-control equipment is available, there is no recourse except to adjust the machine setting through relayed signals.

GERMANY

# Properties of Liquid Contacts

By P. KLAUDY. (From *Elektrotechnische Zeitschrift* (*ETZ*), Vol. 76, No. 15, August 1, 1955, pp. 525-532, 14 illustrations.)

THE contact resistance of electrical contacts consisting only of solid materials (assumed to have absolutely clean contact surfaces) is the result of the non-uniform distribution of the lines of current passing through them. Owing to surface roughnesses, the lines of current are concentrated at small local areas of contact, the conductive material surrounding these is not fully utilized, and an increased resistance is obtained, which has been termed the "constriction resistance" of the contact.*

When a foreign layer (tarnish) is present on the operating surfaces of the contact members, an additional skin resistance occurs. This is always the case with metallic contacts exposed to the influence of air. The skin resistance depends on the nature and thickness of the layer. A distinction is made between the thinnest monomolecular layers, e.g., gas, water, and oil films adhering firmly to the contact surfaces, and the thicker multimolecular layers which, depending on the type and duration of the ambient conditions and temperature, consist of adsorbed foreign atoms or molecules held by van der Waals forces or chemical bonds.

Conduction of current through the very thin layers takes place as a result of the so-called tunnel effect, with very small skin resistances of the order of $10^{-12}$ ohms per square metre of the true area of contact, whereas the thick multimolecular layers act as semi-conductors and have much higher skin resistances. Thus, with the usual contact voltages in technical applications, which are fractions of a volt, no appreciable currents can flow through contacts which are permanently covered with foreign layers of considerable thickness. The flow of current, however, is made possible by the following conditions*:—

(1) When the contact members are pressed together, cracks or gaps are formed in the foreign layers, and in some places the flanks of the gaps are squeezed out in such a way as to allow some of the sound parent metal to come through. Bridges of conductive material are thus formed between the contact members, and the current flows across them in accordance with Ohm's law. Alternatively, if the layers are not fully ruptured but are only squeezed into a film of monomolecular thickness, conduction may also occur, owing to the tunnel effect.

(2) At positions where there is no squeezing effect or rupture, conductive bridges may nevertheless be formed through the layers as a result of "fritting," i.e., partial fusion of the layer material, where the electrical field strength has a sufficiently high value (of the order of $10^8$ volts/metre).

Generally, the true contact areas carrying the load are not only the points where squeezing or fritting has occurred, but also include some of the neighbouring areas. The lines of current from one contact member converge into these areas and expand beyong them in the parent metal of the second member. By using sufficiently high mechanical loads in solid contacts, such as terminal connections, switches, contactors, etc., it is thus nearly always possible to obtain a suitable squeezing effect and hence sufficiently small contact resistances, so as to enable even a heavy current to flow, while maintaining the heat and voltage losses within permissible limits.

## SLIDING CONTACTS OF SOLID MATERIALS AND THEIR LIMITATIONS

In sliding contacts, besides electrical phenomena which differ only slightly from those of "stationary contacts," mechanical problems arise, e.g., frictional losses, wear, danger of rupture due to rough running conditions, shocks, vibration, and resonance phenomena.*

The contact load $f$ is therefore restricted, for instance, to values not exceeding $10^5$ newtons per square metre of apparent contact area (1 newton = 0·102 kg) for carbon brushes on copper or bronze slip-rings. Consequently, the squeezing effect is of secondary importance, and most of the current conduction is due to fritting action. The voltage drop $E_k$ in the partially fused or fritted contacts is between 0·2 and 1·5 V, depending on the type and thickness of the foreign layer; hence, the power $N_i$ dissipated in the form of heat in the fritted sections of two sets of sliding contacts of the type used in electrical machines is $N_i = 2\,E_k I$ [W].

To avoid excessive temperatures and to ensure uniform current distribution among brushes connected in parallel, the current density of the brushes is limited to values $s$ between $5 \times 10^4$ and $25 \times 10^4$ A/m² of apparent contact area. The higher values are for brushes of metal graphite, which are employed to obtain reduced values of constriction resistance with heavy currents. The frictional power loss $N_r$ for two sets of brushes electrically connected in series can be determined as

$$N_r = 2\mu f I v / s \quad \text{[watts]}$$

where $\mu$ = coefficient of friction, $f$ = contact pressure [newtons/m²], $I$ = current [A], and $v$ = sliding velocity [m/sec]. For high sliding velocities and currents, the total losses are considerable. For instance, with $\mu = 0{\cdot}085$, $f = 70{,}000$ N/m², $I = 10$ kA, $s = 200$ kA/m², $v = 60$ m/sec, and $E_k = 1{\cdot}2$ V, the total power loss is $N = N_i + N_r = 60$ kW.

To remove this heat, extensive cooling arrangements are required. In addition, there is the necessity of supervising the large numbers of brushes subject to wear and also the reduction in machine efficiency. Much work is therefore being carried out to improve brush-type sliding contacts. Although this will lead to some progress, there is still the basic difficulty that contact pressures must be kept low to reduce wear, so that, for conduction through the foreign layers, only the fritting effect is available. The power losses with fritting are high for heavy currents. Moreover, carbon brushes, in view of wear and vibration phenomena, are made for sliding velocities not exceeding approximately 60 m/sec. It seemed desirable, therefore, to consider the possibilities of liquid contacts, i.e., of sliding arrangements with liquid paths providing the electrical contact between two members.

## PROPERTIES OF LIQUID CONTACTS

Contrasted with ordinary contacts, liquid contacts can be expected to have a contact resistance which is independent of the liquid pressure and hence of mechanical load. This is immediately understandable for contact members without foreign layers (Fig. 1a), since nothing is altered in the contact conditions by pressure changes, provided that the liquid chamber is hermetically sealed. This, however, is also the case for contact members with surfaces covered by foreign layers (Fig. 1b), because the pressure forces of the liquid on these layers compensate each other in their (horizontal) components. Thus, squeezing effects cannot occur, nor can, for instance, local variations in layer thickness, which might increase the field strength and cause fusion or fritting, as long as it is assumed that the foreign layers are incompressible.

To investigate the extent to which these considerations apply, measurements were carried out, using the

* R. HOLM: Die technische Physik der elektrischen Kontakte. Springer, Berlin, 1941.

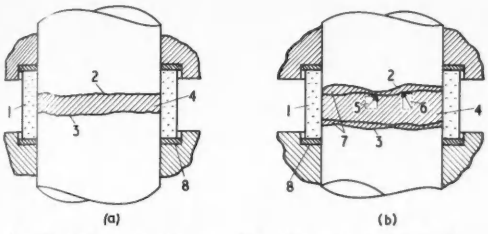


Fig. 1. **Schematic diagram of liquid contacts, with (a) clean contact members and (b) contact members covered with a foreign layer.**

(1) Plexiglas contact ring ; (2) and (3) contact surfaces ; (4) contact liquid ; (5) and (6) pressure of liquid on foreign layer ; (7) foreign layers ; (8) rubber seal.

test arrangement shown in Fig. 2. A thick-walled hollow cylinder (1) of plexiglas or glass contains two contact members (2) and (3). The upper contact member is fitted in the upper support (5), which is of steel, whereas the lower member is located on a plunger which can be adjusted in height by means of a screw (7) in the lower support (8), in order to vary the width $w$ of the contact gap or cavity. The contact liquid is introduced, after evacuation, through a passage (4) in the upper support. The upper section of the passage (4) is then filled with oil, which enables pressure to be applied to the contact liquid. Pressures between zero and 300 atm are thus obtainable by means of a hand pump. Tightness of the contact chamber is ensured by pressing the supports (5) and (8), provided with rubber sealing rings (6), against the cylinder (1).

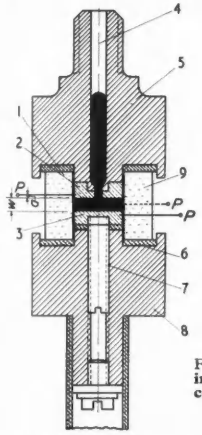


Fig. 2. **Test apparatus for measuring pressure-dependence of the contact resistance of liquid contacts.**

Resistance was determined by measurements of current and voltage, current being indicated by an ammeter in the main circuit, while the voltage was taken from the contact members (2) and (3) by means of probes ($P$) connected to a light-spot galvanometer. The contact resistance was then evaluated by subtracting the " basic resistance " from the total resistance. The basic resistance is calculated from the known values of conductivity coefficients and is defined as the resistance of the contact members and the contact liquid between two probing points, assuming no foreign layers on the contact-member surfaces and a practically homogeneous pattern for the lines of current.

The position of the tappings for the voltage-measuring probes is of considerable importance in obtaining indications of constrictions in the pattern of the lines of current and voltage. If the distance $a$ between the probe and the edge of the contact member is excessive, the basic resistance will be too large to permit the contact resistance to be determined accurately. If it is too small, it may give incomplete data on a closed constriction pattern.

The constriction resistance of one of the media, i.e., its resistance from infinity to the point of emergence of current, can be calculated as

$$R = \rho/4r \quad [\text{ohms}]$$

where $\rho$ = resistivity of medium [ohm-metre] and $r$ = radius of circular aperture [metres]. From the pattern obtained, it has been established that approximately five-sixths of the value of $R$ occurs within a distance of less than three times the diameter $2r$ of the circular emergence area, measured outwards from the centre. Taking account of the size of constrictions occurring on liquid contacts covered with foreign layers, it was found suitable for the tests to use a probe distance $a$ of 0·5 mm from the edge of the contact member.

To eliminate errors due to thermo-electric effects, local effects, and films of water on the probe points, measurements of current were made at constant temperature in both directions. The liquid (mercury) and the contact members were dried in a vacuum, the probe points were annealed in a vacuum, etc. Contact members of various materials were tested, including steel, molybdenum, platinum, rhodium, tungsten, and carbon. Compared with iron, molybdenum has the advantage of better conductivity and higher stability in air.

Before the tests, the surfaces of the contact members were lightly polished and cleaned with benzene, while the mercury used as the contact liquid was freed from foreign matter by passing air through it for several hours and then distilling it in a vacuum.

Table I. Results of Tests Made with the Apparatus Shown in Fig. 2.

| Pressure of contact liquid, atm | Contact current, A | Probe voltage, V | Evaluated total resistance, ohms | Contact resistance (total minus basic resistance), ohms |
|---|---|---|---|---|
| 0 | 0·05 | $16·2 \times 10^{-6}$ | $32·4 \times 10^{-5}$ | $31·7 \times 10^{-5}$ |
| 40 | 0·05 | 16·2 | 32·4 | 31·7 |
| 300 | 0·1 | 28·9 | 28·9 | 28·2 |
| 0 | 0·3 | 88·0 | 29·4 | 28·7 |
| 10 | 0·3 | 86·2 | 28·8 | 28·1 |
| 20 | 0·3 | 86·0 | 28·75 | 28·05 |
| 30 | 0·3 | 85·5 | 28·5 | 27·8 |
| 40 | 0·3 | 85·5 | 28·5 | 27·8 |
| 50 | 0·3 | 85·5 | 28·5 | 27·8 |
| 50 | 1·0 | 256 | 26·2 | 25·53 |
| 100 | 1·0 | 256 | 26·2 | 25·53 |
| 0 | 1100 | — | — | 26·5 |

Details of tests and some of the test results are given in Table I. Confirming expectations, the tests show that, at a constant temperature, the contact resistance of liquid contacts covered with a foreign layer is practically independent of the pressure of the contact liquid (between 0 and 300 atm) and of current intensity, within the range of currents investigated (from 0·05 to 1100 A). In these tests, the contact members were of steel, diameter 15 mm, gap width 1 mm, with mercury used as the contact liquid. The distance between probes was 2 mm, the contact temperature 20° C, the basic resistance $7 \times 10^{-6}$ ohms, the resistivity of the contact members $0·2 \times 10^{-6}$, and of mercury $1 \times 10^{-6}$ ohm-metre.

### Foreign Layers on Liquid Contacts

Contact members exposed to air have foreign layers on their surfaces, and these are responsible for the additional contact resistance. To avoid the formation of these layers, various precautions were tried out, such as turning contact members in a nitrogen atmosphere. The time for turning and installation was shortened to 20 seconds, but, although much lower resistance values were reached in this way, it was not possible to obtain

liquid contacts completely free from foreign layers. It appeared evident that the layers, favoured by the increased temperatures due to turning, were formed on the material in the brief period of exposure to air while the contact members were actually being installed.

It was therefore decided to clean the contact-member surfaces by milling under mercury. Two cylindrical contact members were placed, facing each other, in a hardwood trough and arranged so that the distance between their faces was somewhat smaller than the width of the milling cutter. The trough was filled with mercury and the cutter, immersed in mercury, removed a thin layer from each of the contact members. In the case of contact members made from ferrous material, the shavings were drawn off by means of magnets. The resistance measurements between corresponding probe positions were then taken immediately, i.e., without removing the contact members from the mercury-filled trough.

The measured results were remarkable. At current intensities such as those used in the previous tests, it was no longer possible to determine a drop corresponding to the contact voltage with the aid of the light-spot galvanometer. Measurements with a much more sensitive mirror galvanometer showed that the total resistance between the probes had values of the order of the resistance of the iron and mercury paths alone. The contact resistance had completely vanished, at least for technical applications.

The clean contact members thus produced were left under mercury for some months and tested at regular intervals. It was found that the surfaces remained free from foreign layers, even if the mercury contained dissolved air.

In further tests, the contact surfaces obtained by milling under mercury were exposed, after removal of the mercury from the trough, to environmental influences of various kinds and durations. The trough was then again filled with mercury, and the surfaces were tested to determine their contact resistance. It was found that air at atmospheric pressure and 60% relative humidity produces a layer in a matter of seconds on steel. The thickness of the layer increases with humidity content and time of exposure. Nitrogen and hydrogen also cause foreign layers to be formed, although to a lesser extent.

Very favourable results were obtained with molybdenum, as well as with other substances, e.g., tungsten, chromium, metals of the platinum group, and carbon. To reduce costs and to avoid difficulties in machining, thin coatings of these materials may be used on a different base metal for the contact members (e.g., copper). The coatings can easily be obtained by vacuum deposition, sputtering, or electrolytically.

Corroded iron plates, which are unsuitable for ordinary contacts, also showed, when used in liquid-contact arrangements, a flow of current and relatively low contact resistance, even at low voltages.

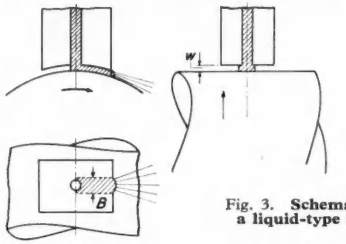


Fig. 3. **Schematic diagram of a liquid-type sliding contact.**

To determine how conduction of current takes place in liquid contacts covered with foreign layers, various investigations were made of the temperature coefficient, time-dependence, and surface condition in relation to the contact resistance. A small negative value was obtained for the temperature coefficient. The results indicate that current conduction at low voltages in liquid contacts with foreign layers occurs as the result of the conductivity of dense layers which are fairly uniformly distributed over the surfaces of the contact members. At higher voltages, i.e., with higher field strengths in the layers, some fusion or fritting probably also occurs. Owing to the intimate contact of the liquid at all points of the layer surface, the contact resistance is much lower than would be obtained with ordinary solid contacts in the absence of squeezing effects, i.e., at low mechanical loads. Therefore, liquid contacts are particularly suitable where, in spite of low contact-actuating forces, it is desired to obtain low contact resistances. The liquid can be replaced, for easier cooling, either intermittently or continuously.

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JAPAN

# The Mechanism of Boron Hardenability

By Y. IMAI and H. IMAI. (From *The Science Reports of the Research Institutes, Tôhoku University*, Series "A," Vol. 7, No. 3, 1955, pp. 249-261, 18 illustrations.)

THE following characteristic phenomena have been recognized in boron-treated steels :—

(i) The characteristic precipitation of "boron-constituent,"[1] observed only in boron-treated steels, shows that boron atoms dissolve in austenite, most of them being localized about the parent austenite grain boundaries at the quenching temperature.

(ii) In the "martensite + troostite" regions in an end-quenched ordinary steel, the grain-boundary nodular troostites clearly delineate the parent austenite grains, while, in a boron-treated steel, the tendency of growth being decreased, these troostites appear randomly as large "patches."

(iii) Boron hardenability reaches a maximum at a definite temperature of heat treatment and then decreases gradually with a rise in austenitizing temperature.

(iv) Boron hardenability is inversely proportional to the carbon content and is essentially negligible in the eutectoid composition.

(v) Influences on the isothermal transformation serve only to delay the beginning of transformation within the range from pearlite to upper bainite.

(vi) The effect of boron does not appear when the rate of cooling is comparatively slow.

Among the above-mentioned experimental observations, (i) and (ii) seem to suggest directly the mechanism of boron hardenability. Grange and Garvey[1] have stated that most atoms of boron added to a steel are concentrated in the vicinity of parent austenite grain boundaries at the quenching temperature and that in the subsequent cooling these localizations of boron atoms may suppress the nucleation of the transformation beginning at grain boundaries. Assuming that a monatomic boron film would be formed around the austenite grain boundaries by surface adsorption,

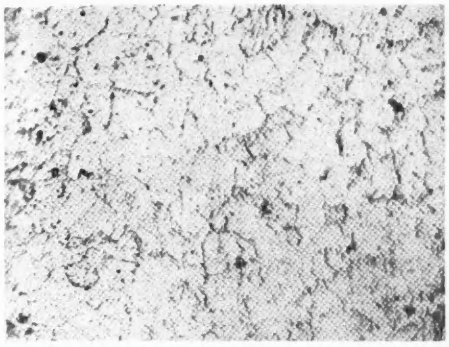

Fig. 1. **Photomicrograph of boron-treated steel; etched with picral.** (×350)

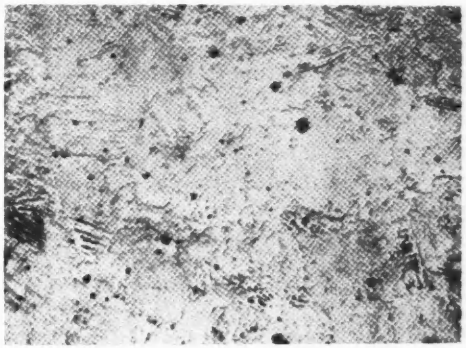

Fig. 2. **Photomicrograph of non-boron-treated steel; etched with picral.** (×350)

Spretnak and Speiser[2] calculated the extent of adsorption of boron atoms necessary to produce these continuous monatomic films and found that the formation of such films was quite unlikely.

Nevertheless, the adsorption of foreign atoms in a solid solution may generally be considered to be one of the most important causes of hardenability, and so, too, must it be the case with boron. In the present work, the grain-boundary adsorption of boron and other interstitial solute elements were metallographically examined with a special etching reagent, and the mechanism of hardening was considered.

## Metallographic Test of Boron Adsorption

A steel containing 0·08% C, 0·5% Mo, and 0·2% Si was compared with a similar steel containing in addition 0·15% Ti and 0·003%B. The mechanical properties of the boron-treated steel indicated an excellent boron effect, these properties being far better, both in the normalized state and in the hardened and tempered state, than those of the steel which had not been boron-treated. These steels were held at 950° C for 30 min and then quenched in water. Photomicrographs of these steels, in the as-quenched state, etched with 5% picral, are shown in Figs. 1 and 2, from which it can be seen that their structures are quite similar. When, however, they were etched with a solution of $NaOH$-$NaNO_3$, as proposed by Beaujard[3], for revealing the segregations of solute elements, differences between them were clearly manifest, as shown in Figs. 3 and 4.

In the boron-treated steel, narrow bands of a dark-brown colour were plainly visible along the parent austenite grain boundaries, and sometimes also along several sub-grain boundaries of the parent austenite. On the other hand, in the case of the steel which had not been boron-treated, no coloured bands were observable. The dark-brown bands in the case of the boron-treated steel may be assumed to show the local concentration of a number of solute elements by surface adsorption.

Considering the fact that the characteristic precipitation is formed only in a boron-treated steel, it is certain that the boron atoms are concentrated in the vicinity of parent austenite grain boundaries. To obtain the evidence of the adsorption of boron, a simple test was carried out with a steel containing 0·01% C and 0·0004% B, and made from iron of fairly high purity by melting in a high vacuum. This steel was held at 1000° C for 10 min and then quenched in ice water. Once again, photomicrographs, using a solution of $NaOH$-$NaNO_3$ as etchant, showed coloured bands along the parent austenite grain boundaries, similar to those in Fig. 3. In this case, however, the width of the bands was more or less increased and breaks were apparent along the boundary, these breaks being merely an indication of comparatively low boron content, 0·0004% B being perhaps the lowest limit for effective hardening.

To investigate what elements, other than boron, were also capable of being adsorbed, the microstructures of the four plain carbon steels, *A*, *B*, *C*, and *D*, shown in Table I, were similarly examined. Steels *A* and *B*, strongly deoxidized by adding respectively

Table I.

| Steel | Percentage Composition | | | | |
|---|---|---|---|---|---|
| | C | Si | Mn | Ti | Al |
| *A* | 0·13 | 0·2 | 0·2 | 0·15 | — |
| *B* | 0·13 | 0·2 | 0·2 | — | 0·2 |
| *C* | 0·15 | — | — | — | — |
| *D* | 0·20 | 0·2 | 0·2 | — | — |

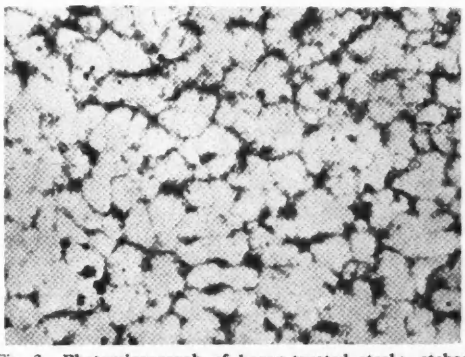

Fig. 3. **Photomicrograph of boron-treated steel; etched with solution of $NaOH$-$NaNO_3$.** (×350)

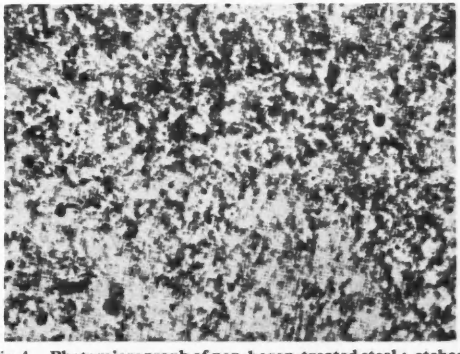

Fig. 4. **Photomicrograph of non-boron-treated steel; etched with solution of $NaOH$-$NaNO_3$.** (×350)

0·15% Ti and 0·2% Al, also showed the presence of coloured grain-boundary bands, using a solution of $NaOH$-$NaNO_3$ as etchant. On the contrary, however, in the case of steel *C*, which had been melted in a vacuum, and steel *D*, which had been deoxidized only by Si, no such coloured bands were produced. In the case of a plain carbon steel, it appears reasonable to assume that the segregating elements consist mainly of carbon, because of its high diffusion rate and its high content, compared with nitrogen and oxygen, among other elements.

### Metallographic Test of Boron Adsorption and the Formation of "Boron-Constituent."

The characteristic precipitation of "boron-constituent"[1] appears only in a boron-treated steel when it is rapidly cooled from an extremely high austenitizing temperature, say, about 1100° C, to the temperature below the eutectoid transformation point.

To ascertain the effect on adsorption of raising the austenitizing temperature, two specimens of a steel, containing 0·08% C, 0·3% Mo, 0·2% Si, 0·3% Ti, and 0·003% B, were heated to 1000° C for 30 min, and 1100° C for 10 min, respectively, and then water-quenched. In the resulting photomicrographs, using as etchant a $NaOH$-$NaNO_3$ solution, the grain-boundary bands were of extremely narrow width, especially in the case of the steel heated to 1100° C. In addition, another specimen of this steel was heated to 1100° C for 10 min, cooled in the furnace to 1000° C and held for 30 min, and then water-quenched. The resulting photomicrograph was similar to that of the steel heated to 1000° C for 30 min.

From the changes in these features of grain-boundary bands, it can be said that the adsorption of solute atoms into the grain surface proceeds with a rise in the austenitizing temperature, resulting finally in revealing the "boron-constituent."

### The Influence of Austenitizing Temperature on the Hardenability of Boron-Treated Steel

Many experiments have been reported on the influence of austenitizing temperature on the hardenability of boron-treated steel, but their results are not always in good agreement. It is generally accepted, however, that the effect of boron on hardenability gradually decreases with an increase in austenitizing temperature.

To check the influence of austenitizing temperature on the hardenability of boron-treated steel, five steels, of the compositions shown in Table II, were prepared. These steels were austenitized at various temperatures between 950 and 1100° C and then normalized.

Table II.

| Steel | Percentage Composition | | | | |
|---|---|---|---|---|---|
| | C | Si | Mo | Al | B |
| No. 1 | 0·08 | 0·2 | 0·70 | — | — |
| No. 2 | 0·09 | 0·2 | 0·73 | 0·11 | 0·003 |
| No. 3 | 0·09 | 0·2 | 0·73 | 0·20 | 0·003 |
| No. 4 | 0·09 | 0·2 | 0·73 | 0·33 | 0·003 |
| No. 5 | 0·09 | 0·2 | 0·73 | 0·41 | 0·003 |

With a rise in austenitizing temperature the grains of steel No. 1 became coarse and homogeneous, and hardenability increased. In the case of the boron-treated steel No. 2, however, hardenability gradually decreased, and the effect almost disappeared with austenitizing at 1100° C. In the case of the other boron-treated steels (3, 4, and 5), all of which were strongly deoxidized by excessive additions of Al, the effect of boron was fairly well established at the maximum austenitizing temperature of 1100° C.

From these observations, it may be said that the austenitizing temperature had no influence upon the boron hardenability when a steel was treated with an excessive amount of deoxidizing agent.

The reason for the disappearance of boron effect with a rise in austenitizing temperature under a relatively small amount of deoxidizing agent is that the specimens are deoxidized and denitrogenized by the addition of Al, producing large amounts of aluminium oxide and aluminium nitride.

From the experiment of Born and Koch[4], it is well recognized that aluminium nitride is easily re-dissolved in austenite at temperatures above 1000° C. Consequently, the nitrogen content in the steel will rapidly be increased when the austenitizing temperature is raised above about 1000° C. Moreover, from the experiment of Digges and Reinhart[5], it is well known that boron hardenability rapidly decreases with an increase in nitrogen content in the solid solution of steel.

When titanium was used in place of aluminium, a decrease in boron hardenability with an increase in austenitizing temperature was not manifested, even with the addition of 0·1% Ti. From the fact that experiments show that titanium nitride does not re-dissolve in austenite at about 1100° C, it may be concluded that an increase in nitrogen content in the solid solution with a rise in austenitizing temperature is not as conspicuous in a steel deoxidized with titanium as in one deoxidized with aluminium.

### The Mechanism of Boron Hardenability

It has been reported [6,7] that boron has no important effect on the diffusivity of carbon in austenite. Furthermore, from various observations on boron-treated steels, it has been known that the mechanism of boron hardenability differs considerably from that of the usual alloying elements, such as Ni, Cr, or Mn.

From the results already mentioned, it becomes clear that boron hardenability is due mainly to the grain surface adsorption of boron and other atoms, the mobility of which in austenite is comparatively high. The most characteristic aspect of boron hardenability may be said to be a remarkable suppression of the nucleation of transformation, beginning at the austenite grain boundary. Owing to the large atomic size of boron as an interstitial solute element and to its high mobility[7] in austenite, boron atoms adsorbed on the grain surface will effectively fill up lattice imperfections, and the internal strains due to these imperfections will be reduced. Thus, the nucleations beginning at grain boundaries will be suppressed until the steel is cooled to a sufficiently low temperature. The alternative interpretation is as follows:—Boron atoms adsorbed on the grain surface may form a "Cottrell atmosphere" during cooling, giving rise to the anchoring of dislocations in the vicinity of grain boundaries, because these dislocations play an important role in the formation of the nucleus of $\alpha$-iron by quenching.

Spretnak and Speiser[6] have proposed the following mechanism:—The transformation of $\gamma$-iron into $\alpha$ will be carried out by the nucleation and shear mechanism instead of the usual nucleation and growth mechanism. The high strain energy in the austenite lattice due to boron atoms will be effective in retarding the shear transformation of $\gamma$-iron. Based on the relations between lattice parameters, concentrations, and diameters of solute atoms, they calculated the ratios of hardenabilities due to carbon, nitrogen, and boron as 1 : 3 : 50. It is more likely, however, that the weak

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# Improvements in Nitriding

By G. KELLER. (From *The Brown Boveri Review*, Vol. 42, No. 3, 1955, pp. 88-93, 12 illustrations.)

*Although nitriding is a well-known method of surface treatment, its use has not been as general in the past as it might have been. Now, however, that it can be controlled, its value will be considerably enhanced, as treated workpieces will be able to withstand much more severe conditions than were hitherto possible.*

ALTHOUGH it is known that the resistance of annealed nitriding steel is increased nearly twenty times by nitriding, and that a nitrogen-hardened testpiece exhibits only one-third of the wear experienced by a case-hardened steel, the application of nitriding has so far not been particularly wide-spread. In all probability, this is due partly to the fact that, until quite recently, insufficient allowance could be made during nitriding for the wide range of conditions to which treated workpieces would be subjected in the manifold applications likely to be encountered. Thus, the results expected from nitriding were in many cases not entirely fulfilled. Depending on the particular application in question, the nature of the loading might be only frictional or, in addition, concentrated, or might perhaps take the form of shock or vibration. The effect, among others, was that the nitride layer peeled off and led to considerable damage, eventually bringing the process of nitriding into disrepute.

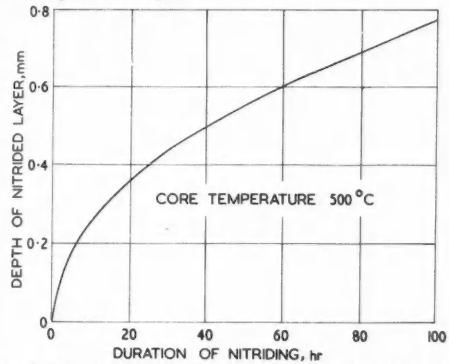



Fig. 1. **Depth of the nitride layer as a function of duration of nitriding.**

Scientific research at the Swiss Federal Ordnance Factory in Berne led to the discovery of a means of controlling the process of nitrogen hardening, which enabled its scope to be appreciably extended. The depth of the layer depends on the length of time allowed for nitriding, and with the conventional method reaches values as shown in Fig. 1, although the effective hardness does not bear a direct relationship to the thicknesses indicated by the ordinates of this curve. Hardness follows the curve in Fig. 2, the shape of which is governed by the type of steel chosen.

The sharp diminution in hardness through the nitride layer is a serious handicap in certain applications, especially where the workpiece is subjected to final grinding; this frequently involves sacrificing the layer most resistant to wear, robbing the process of its main attraction. This hard layer, however, is insufficiently resistant to impact loads and peels off quite easily.

The ability to control the shape of the curve, i.e., the hardness of the outer layer and the depth of the nitride layer, represents a definite advance. It is now possible for the process to be employed with great success in numerous cases where hitherto this appeared to be out of the question. Nitriding of gear-wheels, armaments, valves and valve seats, crankshafts, and other machine parts subject to wear from impact or pressure loads may be mentioned in this respect. One particularly difficult problem, i.e., nitriding the inner surface of long, narrow, hollow objects, such as gun-barrels, is likewise solved by the new process.

For a nitrogen-hardened workpiece to be able to withstand the severest conditions, it is essential for the original material to be of the best quality. Together with the appropriate heat treatment associated with nitriding, the control of the process assumes decisive importance. A well-known fact, which unfortunately had always to be accepted, was that nitriding caused embrittlement of the core, resulting in a reduced impact strength. The new method not only overcomes this embrittlement, but also partly lessens existing brittleness. Workpieces hardened by the new process have an impact strength which, if not higher, is at least as good as that of the untreated object. Reproduced in Fig. 3 is a number of typical nitriding curves which can

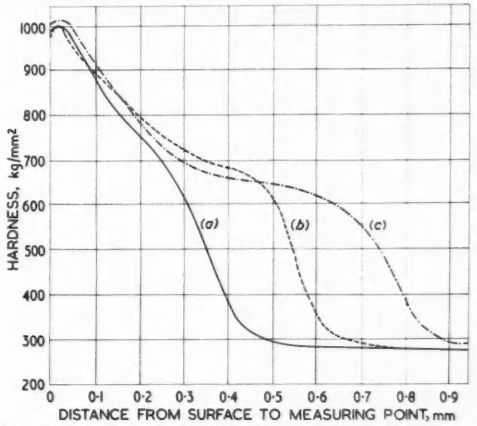



Fig. 2. **Effect on Vickers hardness, with a 100-gm load, of nitriding for (*a*) 48 hr, (*b*) 93 hr, and (*c*) 141 hr.**

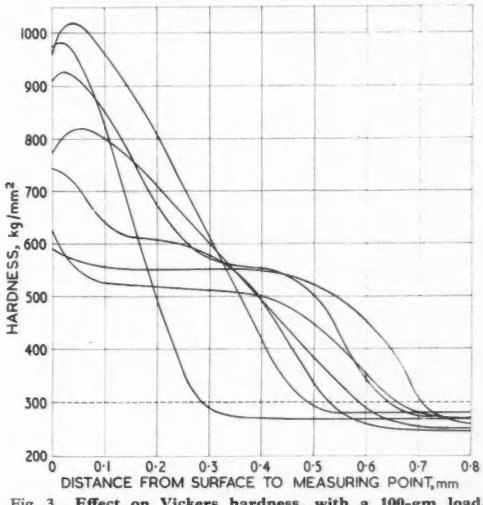



Fig. 3. **Effect on Vickers hardness, with a 100-gm load, using the "controlled-nitriding" process.**

be obtained with the same quality steel by appropriately varying the heat treatment and control of the hardening process. From these can be deduced the extent to which allowance can be made for the various operating conditions when applying the new nitriding process to a workpiece.

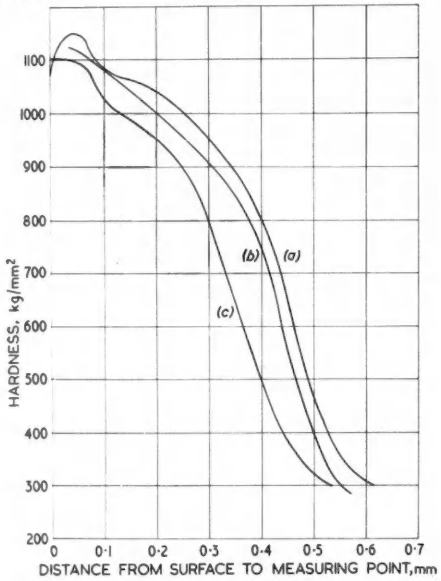



Fig. 4. **Results of Vickers hardness tests on nitrided steel, using loads of** (*a*) **100 gm,** (*b*) **500 gm, and** (*c*) **30 kg.**

Unfortunately, there are no universal standards for determining the depth of hardening, a fact which is also true of the method of determining hardness. Depending on the force applied to the diamond tip, it is possible to record appreciable variations in the hardness (Fig. 4); this is serious when determining the depth of hardening. Continuous production inspection does not permit the test surface to be highly polished, as this would take too long; therefore, deep impressions are necessary to limit the divergence of results, and this can be achieved only by applying a high load to the diamond tip. For scientific purposes more time can be devoted to preparing the test object, so that loads of 0·5 or even 0·1 kg are effective. For production tests, however, loads of from 5 to 10 kg are suitable. The latter are applied perpendicular to the hardened layer, whereas research tests follow the line of the layer itself.

To carry out the process and to obtain the results described it is essential that the plant should be capable of supremely accurate temperature regulation and should be absolutely gas-tight. The first condition can be fulfilled only by electrically heated furnaces equipped with precision instruments for regulating the temperature. Practical experience has shown that the second condition can be fulfilled only by nitriding containers having a seal well away from the zone in which the furnace temperature prevails, i.e., on the top of the furnace. For Brown Boveri, who at one time were sole licensees for the Grünewald bright-annealing pot, it was quite natural that their nitriding furnaces would follow the same principle, ultilizing experience gained from several hundred furnaces employing this system. The design of furnace and pot, therefore, based on long experience, required only the application of the latest results of research carried out at the Federal Ordnance Factory to enable it to achieve the success described. Fig. 5 shows a section through such a nitriding plant, which is a vertical furnace with a heavy steel jacket. The heating elements, made of chrome-nickel alloy containing no iron, are suspended on tubular ceramic supports and arranged hexagonally around the inner wall of the furnace. The extreme protraction of the nitriding process demanded the devotion of particularly close attention to the question of thermal insulation. With the exception of the smallest types, all furnaces can be connected to three-phase supplies up to 500 V. The refractory lining, heating resistances, and insulation are dimensioned to permit annealing to be carried out at up to 960° C. Thus, besides nitriding, the furnace can be used for all other heat-treatment processes.

The nitriding tank is suspended inside the furnace, its weight being taken by the cover ring. The pot, made from chrome-nickel alloy steel sheet, is suspended from the cooling ring, which prevents overheating of the rubber gasket. The cover is made of the same material as the pot and is packed with insulation. On the side of the insulating cover are slots, into which are fitted the heat-resistant suspension rods carrying trays or hangers for the material or objects to be nitrided or annealed.

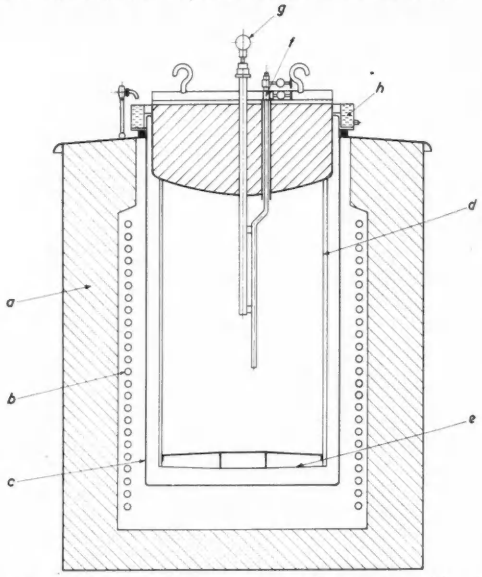



Fig. 5. **Section through vertical nitriding furnace, with pot in position.**

(*a*) Furnace.
(*b*) Heating elements.
(*c*) Pot container.
(*d*) Suspension rods.
(*e*) Tray.
(*f*) Gas inlet and outlet valves.
(*g*) Thermostat.
(*h*) Cooling ring.

The absolute tightness of the pot prevents the ingress of unwanted air and the escape of nitriding gases during the process, a problem which no longer presents any inconvenience to the worker in such a plant. That this efficient seal reduces ammonia consumption to an extremely low level—only about 0·2 $m^3$/hr per $m^3$ of container volume—is an added advantage of these nitriding plants. Specially designed gauges record the rate of flow of the gas and its degree of utilization; the used gas is specially oxidized and rendered odourless.

The switchgear consists of the necessary contactors and temperature regulators. The value of the nitriding charge usually warrants the incorporation of a temperature recorder, which furnishes documentary proof of the quality of the nitriding. To make perfectly sure that the temperature of a charge is uniform, the furnace, depending on its size, contains independently regulated vertical heating elements; the same object can be achieved with fans in the pot cover, or a combination of both.

# Valves for Corrosive Fluids

By E. G. HOLMBERG. (From *Corrosion*, Vol. 11, No. 9, September 1955, pp. 58-66, 11 illustrations.)

*When proper consideration is given to, among others, such important factors as alloy selection and the design of components for a particular set of service conditions, it is possible to write valve specifications which will ensure virtually maintenance-free service for many years.*

THERE are available many so-called corrosion-resistant alloys which have good engineering properties and which are available in practically all forms, e.g., pipe, rods, sheet, and castings. However, in the use of many special alloy compositions, practical difficulties may be encountered. Thus, for instance, the alloy might easily be available only in the cast form, and even then the number of castings required might have to justify pouring a full heat of the smallest capacity a foundry could produce. Furthermore, it might be found that many of these special compositions could be rolled into sheet or drawn into bars and tubes only with difficulty.

The sources, in descending order of reliability, from which data can be obtained (in the absence of directly applicable experience) for making an alloy recommendation can be listed as follows :—

(a) Corrosion tests conducted within vessels or solution lines of a full-scale operating unit.

(b) Corrosion tests conducted within a pilot plant built to study the process characteristics.

(c) Laboratory corrosion tests conducted in synthetic solutions and in equipment designed to reproduce or approximate conditions which will be encountered in a full-scale unit.

(d) Corrosion test data available for materials used to handle solutions of a similar or preferably identical composition, at pressures, temperatures, and velocities comparable with those that will exist within the unit.

Obviously, if a chemical process is entirely new, representing an improvement over some previously employed process, or is designed to make an entirely new product, one of the last three methods designated will be employed for selection of the proper materials of construction. When it is necessary to select alloys for the construction of a new operation by one of these three methods, experience has indicated that corrosion tests should be conducted after the plant starts producing, to determine the accuracy of the alloy selections and also to evaluate other less expensive alloys.

## THE DESIGN OF VALVE COMPONENTS

Each of the components used in the assembly of corrosion-resistant valves is described in the following, together with the reasons for selecting specific designs.

### (1) VALVE BODY

*(a) General :—*

The valve body can be considered the heart of a valve, as its performance frequently will determine the success or failure of a particular design. For valves required to handle a wide variety of corrosive solutions, the body should be provided with suitable end connections, bonnet connection, and seating surfaces which will not, because of design, aid a particular corrosive process which the solution conditions may tend to promote. The wall sections of the body should be of ample thickness to provide adequate strength, ensuring freedom from dimensional changes when subjected to the maximum pressure for which the valve is designed, normal line stresses, and normal stresses imposed when tightening the valve disc or discs into, or opening from, the closed position.

*(b) Threaded Connections :—*

Threaded connections have not been entirely successful as a dependable leak-proof method for the assembly of valves into a piping system conveying a corrosive solution. Threaded connections leave a crevice on the inside of the pipe where crevice-corrosion can occur. Should the solution being handled promote this form of attack, the connection eventually will leak and will be weakened by metal loss. Seal welding will serve to improve the performance of these connections by preventing air and moisture from the atmosphere intermixing with any solution that may work its way between the threads.

Many corrosion-resistant alloys have a strong tendency to gall when in bearing contact. This is particularly true for all grades of austenitic stainless steels. When threaded connections are used for the assembly of equipment fabricated from these alloys, difficulty frequently is encountered in attempting to obtain complete thread engagement, because the threads will gall before this is accomplished. To minimize galling, it is mandatory that threads cut in these materials should have the proper dimensional tolerances and should be free from rough edges and tears.

Most so-called "pipe dopes" have been only partially successful as an aid in obtaining a tight seal and overcoming the galling tendency. Some have insufficient anti-friction properties, so that, even when dopes are used, galling will occur. Others, although good anti-friction compounds, leave between the threads a film which is not resistant to the corrosive to be conveyed; when this material is decomposed, a loose and leaky connection results. It would appear that the most successful anti-friction lubricant for threaded connection of austenitic stainless steels is molybdenum disulphide, either as a powder or a paste.

Considering these factors, it also can be concluded that the male-female threaded connection for securing the valve bonnet to the valve body (Fig. 1) may likewise be considered an undesirable design. Should it be considered practical because of size to secure the bonnet by means of a threaded connection, the union-ring bonnet construction (Fig. 2) is preferred. The threads of this type of connection will not be directly in contact with the process solution.

*(c) Flanged Connections :—*

Flanged connections have been found most satisfactory for valve bonnets and piping connections. Some designs are preferred, while others are questionable. Preferred designs include those of the plain-face, raised-face, large and small male-female, and lapped types, while questionable designs are those of the large and small tongue-groove, and ring-joint types.

The qualifications for each design can be summarized as follows :—

In the *plain-face* design, a soft, compressible sheet gasket material, e.g., asbestos or rubber, is cut to cover the entire facing between the flange i.d. and o.d., and is used to seal the joint between the flanges. Because of a relatively low compressive force per unit gasket area, as compared with other designs, full-face metal-jacketed or spiral-wound gaskets are not successful when used with this type. Provided that a gasket material resistant to the corrosive is employed and that the internal diameters of the gasket and the pipe are the same, flanges of this design provide a smooth, continuous connection. This freedom from crevices or pockets, in which sediment or corrosion products may accumulate to cause concentration cell corrosion, is a necessary feature.

Flanges of the *raised-face* design have all the merits of the plain-face flange, plus the added advantage of being suitable when employing relatively hard gasket materials. When properly tightened, the compressive force developed per unit gasket area will permit the use

of metal-jacketed or spiral-wound gaskets between flange faces machined with a smooth finish.

To *large and small male-female* flanges the remarks made for plain-face and raised-face flanges also apply. From a standpoint of safety, for some high-pressure conditions these flanges would probably be preferred, since, if a gasket failure occurs because of decomposition, there would be only a slight possibility that a high-velocity stream would flow directly from the flange joint. It will be observed that, when a gasket of proper thickness is used, the contact surface of the male flange will be below the outer face of the female flange. Also, it is obvious that this construction will reduce the possibility of a gasket blowing out.

The *lapped* flange with stub end will form a connection when bolted to another lapped flange with stub end, or to a raised face which will be practically identical with that formed by two raised-face flanges. Both hard and soft gasket materials can be used to seal the connection. A crevice will not exist at the joint when the interior diameter of the gasket is cut to conform with that of the pipe.

With *large and small tongue-groove* flanges, gaskets of practically all types can be used. Although their construction will completely retain the gasket, they have the objection, when finally made up, of leaving a crevice or gap between the flanges, of a width equal to the final compressed thickness of the gasket. For handling corrosive fluids, where it is known that crevice-corrosion can develop, these flange designs should be avoided. For non-corrosive media at high temperatures and pressures, in conjunction with the use of a metallic gasket, they should be quite satisfactory.

*Ring-joint* flanges were designed originally for application in high-temperature, high-pressure piping systems required to convey non-corrosive media. They are rarely used in low-pressure piping systems conveying corrosive solutions, because their application is limited to the availability of metal ring gaskets of proper hardness and adequate corrosion resistance. Ring-joint flanges also have the objection of leaving a gap (where crevice-corrosion can occur) at the flange joint, when finally made up. The width of this gap is an important consideration in the design of these flanges.

(*d*) *Body Seats* :—

Valve bodies designed for corrosive applications have seating surfaces which are integral with the body. The mechanical desirability of the renewable-seat ring design has been sacrificed in valves required to handle corrosive fluids, because corrosion resistance must be given preferred consideration.

When solutions are handled which contain abrasives causing scoring of the seating surfaces, it would appear that hard-facing of these surfaces is not always the solution. Valves of globe or " Y " design, having discs with Teflon inserts, have been found most satisfactory. Upon seating the disc of this design, the abrasive particles will imbed in the Teflon without causing damage to the metal seating surface or inability to effect a tight closure.

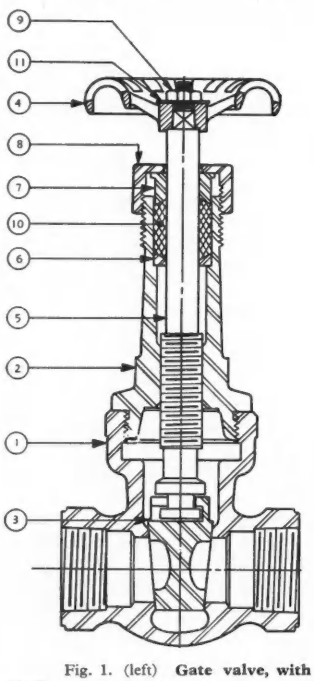
(2) VALVE DISCS

(*a*) *Gate Valves* :—

The disc, gate, or wedge in gate valves (Fig. 1) can be either of two-piece or one-piece construction. There are two principal double-disc designs—the double wedge and the ball-and-socket wedge (Fig. 3)—used in valves required to handle corrosive fluids. The double wedge is composed of two discs, each having identical dimensions and shaped like a cupped hand. When installed, they are placed back to back, so that the machined faces will contact the body seating surfaces in the closed position. A groove, at the top of each disc, is machined to fit a milled slot in the stem foot, from which each is suspended. This design has the objection of being susceptible to wear at the stem connection, and excessive wear will permit either one or both discs to become disengaged.

A disc design, which the writer believes to be better than the above, is the ball-and-socket type. One disc has a ball machined on the back, which, when in the assembled position, will fit into a socket machined in the back of the second disc. This design will permit considerable wear in both the disc holder and ball-and-socket joint without either disc becoming disengaged. It also has an advantage over other designs in that the discs are free to rotate and will not seat along identical surfaces upon repeated closure. Experience would indicate also that the ball-and-socket wedge has far less tendency to cause galling of the seating surfaces.

As also shown in Fig. 3, the one-piece disc can be either a solid-wedge or cored-wedge design. As each of the body seats in valves employing wedges of this type is generally machined at an angle of 5 deg. to the vertical axis of the valve, disc faces are machined to form an included angle of 10 deg. The solid wedge is used in valves required to handle solutions that do not have entrained solids which may settle in the pocket beneath the seating surfaces and thus interfere with full



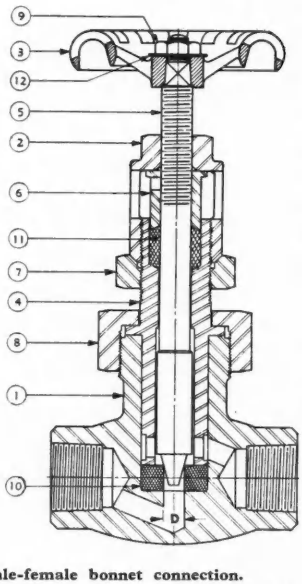




Fig. 1. (left) **Gate valve, with male-female bonnet connection.**
(1) Body ; (2) bonnet ; (3) wedge ; (4) handwheel ; (5) stem ; (6) packing ring ; (7) gland follower ; (8) packing nut ; (9) wheel nut ; (10) packing ; (11) identification plate.

Fig. 2. (right) **Needle valve, with union-ring bonnet connection.**
(1) Body ; (2) packing nut ; (3) handwheel ; (4) bonnet ; (5) stem ; (6) gland follower ; (7) packing-nut locknut , (8) union ring ; (9) handwheel nut ; (10) seat ; (11) packing ; (12) identification plate.

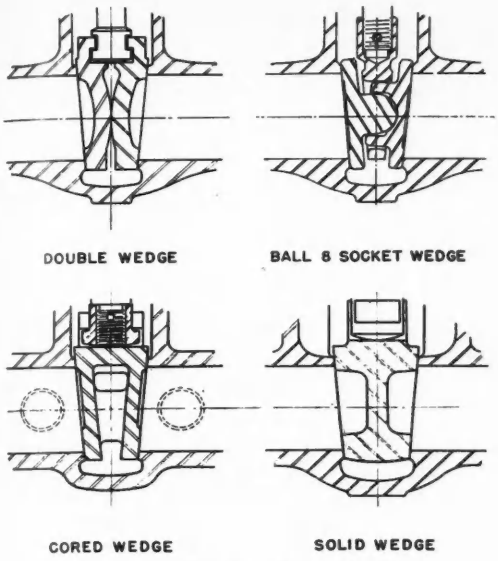



Fig. 3. **Principal designs of gate-valve discs.**

travel of the gate. The cored wedge, however, will perform satisfactorily when this pocket contains an accumulation of solids, because the two rather narrow lips at the bottom of the disc will cut into the solids and force them into the cored-out area within the wedge. When the valve is opened, turbulence will wash away any solids the wedge may have retained. Both designs usually are provided with a " T " slot at the top to receive the stem which actuates the disc.

(*b*) *Globe, Angle, and " Y " Valves :—*

Globe, angle, and " Y " valves are usually designed to have the stem rotate when the handwheel is turned to perform either the closing or opening operation. As this action would result in galling of the seating surfaces if the disc were an integral part of the stem, the swivel-disc design is used. These discs in valves constructed of austenitic stainless steels and other corrosion-resistant alloys have been of various types, i.e., the modified-plug, ball-plug, renewable-disc, and " V "-port-plug, as shown in Fig. 4. The disc of each design is secured to the stem by means of a swivel nut machined to fit over a shoulder at the stem foot. After complete thread engagement, it is important that the disc and swivel nut be pinned, to prevent their coming apart while in use.

The seating surface of the modified plug is machined to form an included angle of 30 deg., and the seating area is reduced to approximately one-third of that for a full body seat. Experience has shown that this is more reliable in producing a consistently tight closure with a minimum of handwheel tightening.

The seating surface of the ball plug is machined on the radius of a sphere, while the body seat is machined at an angle of 45 deg. When the plug is in the closed position, line contact will be made around the seating surface. This is normally preferred for handling solutions which have suspended crystal particles or which may tend to crystallize on seating surfaces.

In the renewable-disc design, various non-metallic materials, as well as soft metals, can be secured within the disc holder. Teflon, because of its outstanding resistance to a wide range of corrosives, has been found an excellent material for these discs. The renewable-disc design will ensure tight closure when handling solutions which contain entrained solids tending to deposit on seating surfaces. On closure, solids will imbed in a soft disc material and thus will not interfere with obtaining a tight shut-off, as would be the case with metal-to-metal seating. This design will also permit the use of less expensive alloys which have a borderline corrosion resistance to the fluid being handled. An etched condition of the body seat will not interfere with obtaining a tight shut-off, because the roughened surface will imbed in the soft disc. It is also an excellent design for vacuum service.

Still another design of globe valve, varying somewhat from the standard type, is that employing a " V "-port disc, which is an adaptation of the type used in most motor-operated flow-control valves. The seating surfaces of the " V "-port disc are machined at an angle of 45 deg. As shown in Fig. 4, the disc is constructed with a skirt, in which there are " V "-port openings, permitting closer fluid control than can be obtained with globe-valve discs of conventional designs. As the fluid passing the disc would cause it to rotate at a relatively high velocity, valves of this design are constructed with a non-rotating rising stem, permitting pinning the disc to the stem.

(*c*) *Needle Valves :—*

Conventionally designed needle valves, having a disc or needle-point integral with the stem (Fig. 2), have not been entirely successful when used to handle corrosive fluids and when constructed of corrosion-resistant materials which tend to gall. The relatively short service life of these valves has been found to be principally the result of galling at the seating surfaces. It has been discovered, however, that this weakness in needle valves can be eliminated by employing a corrosion-resistant soft-seating material, such as Teflon.

(*d*) *Check Valves :—*

The most common type of valve employed to control the directional flow of fluids in piping systems is the swing-check valve. This valve is equipped with a single disc suspended by means of an arm secured to the valve cap or at a suitable point within the valve bonnet. The disc is machined with a flat seating surface which contacts a similar surface, machined at an angle, usually 5 deg., around one opening into the body area.

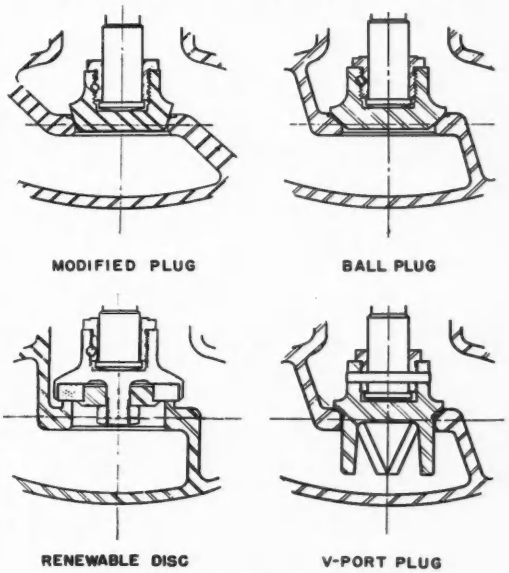



Fig. 4. **Principal designs of globe-valve discs.**

Should a tighter closure be desired for some conditions obtainable with metal-to-metal seating, the renewable-type disc can be used.

The second most popular check valve is of the lift type, the use of which is generally confined to small-diameter piping. The disc in this valve has a stem as an integral part. The stem, which passes through a suitable sleeve in the bonnet, controls the movement of the disc and ensures proper seating. The most satisfactory seating surface will produce line contact.

The ball-check valve is another type; however, it has not been extensively used for controlling the flow of corrosive fluids, as balls are available in only a very limited number of alloys. Glass balls, which would be resistant to a wide range of corrosive fluids, have the weakness of cracking or chipping easily.

(*e*) *General* :—

Special valves, such as flush-bottom tank valves, sampling valves, gauge-glass valves, jacketed valves, etc., employ in their construction discs of one of the foregoing designs.

For good performance of all valve-disc designs made from corrosion-resistant alloys, special machining techniques must be employed to obtain surfaces with a high degree of dimensional accuracy. Seating surfaces must be machined extremely smooth, and must be free from scores and irregularities which may cause galling or interfere with obtaining complete shut-off.

(3) Valve Stems

(*a*) *Design Details* :—

The modified acme thread has been adopted as standard for stems machined from austenitic stainless steels and other high alloys.

Most stem designs are provided with a shoulder which contacts a seating surface machined in the bottom of the bonnet below the packing gland. This will serve as a back seat when the valve is in the wide-open position and will permit repacking of the valve while under pressure. The stem foot to which discs are secured is machined in various ways to accommodate the particular disc design.

(*b*) *Machining* :—

Extreme care must be exercised in the machining of stem threads to produce surfaces smooth and free from tears. The unthreaded portion of the stem, particularly the area which will comprise the packing travel, must also have a smooth finish, to ensure a proper seal when in contact with the packing.

(4) Valve Bonnets

(*a*) *Design Variations* :—

Valve bonnets are of two principal designs, i.e., inside screw, and outside screw and yoke, respectively. The base of the bonnet is machined for either a male-female, a union-ring, or a flange connection.

(*b*) *Male-Female and Union-Ring Bonnets* :—

Bonnets having either the male-female or union-ring bonnet connections (Figs. 1 and 2) usually have threads machined on the inside bore (inside screw) below the packing gland for controlling the stem movement. As these threads will be in contact with the solution and therefore subject to some metal loss because of corrosion, the inside-screw design is not considered best suited for corrosive applications. Such a modification, however, as threading of the packing nut to place the packing between the solution and the stem thread is quite an acceptable design (Fig. 2). As previously stated, the union-ring bonnet connection is preferred to the male-female design.

(*c*) *Outside-Screw and Yoke Bonnet* :—

The outside-screw and yoke bonnet, with a threaded bushing at the top for actuating the stem, and a flange at the base with a minimum of four bolts for securing the bonnet to the body, is the preferred design for all valve types. The two-bolt bonnet-flange construction should be avoided because of the hazard that would be imposed should one bolt fail as a result of corrosion or defective material.

(*d*) *Packing Glands* :—

Packing glands in all valve bonnets should have sufficient depth and diameter to permit installation of standard packings capable of producing a tight seal at the temperature-pressure ratings for the particular valve design.

(*e*) *Gland Plate and Follower* :—

To be assured of the straight downward travel of a packing follower, the two-piece gland plate and follower, with a ball-and-socket connection between the two, has been found very satisfactory. Should the gland plate of this design become cocked, because of uneven tightening on the gland bolt nuts, the force that could be applied will not be transmitted to cause excessive binding of the follower on the packing-box wall or stem.

(*f*) *Bolting* :—

Stainless-steel type 303 nuts with stainless-steel type 304 bolts are representative of the minimum alloy combination acceptable for bonnet and packing-gland bolts and nuts. Because valve bolting is not directly in contact with the solution, bolts and nuts of these alloys have been found very satisfactory for practically all conditions. Some special applications require more highly alloyed bolting materials to be used.

## Properties of Liquid Contacts

(*Concluded from page* 518)

Liquid-Type Sliding Contacts

An example of an arrangement for a liquid-type sliding contact is given in Fig. 3. It should be noted that liquid contacts with relative motion between the contact members have, under otherwise similar conditions, contact resistances of the same order of magnitude as stationary liquid contacts. When the materials mentioned above are used for the contact members, it is possible, in technical applications, to obtain contact resistances of the order of $10^{-3}$ to $10^{-4}$ ohms, even with contact-member surfaces covered with foreign layers, using contact surfaces of a few square millimetres.

The losses occurring are (a) losses due to heat in the foreign layer or current constriction and in the basic resistance (the latter being negligibly small); (b) losses due to viscous friction at the boundaries and in the liquid, with eddies forming in the liquid; and (c) kinetic losses, corresponding to the velocity imparted to the liquid by the moving contact member, which generally cannot be recovered after the liquid has emerged from the contact gap.

Compared with the friction of solid contacts, fluid friction is very small and indicates that liquid contacts should be most suitable for sliding-contact applications. With correct designs, i.e., small contact-member surfaces which are kept free from foreign layers, and a narrow contact gap, kept short in the tangential direction, liquid contacts are superior to solid-type sliding contacts, both electrically and mechanically.

The power losses $N_r$ and $N_k$ due to viscous friction and kinetic-energy dissipation can be evaluated as follows :—

$$N_r = \eta_l A v^2/w,$$
$$N_k = \gamma v^3 B w/16,$$

where $\eta_l$ = viscosity of contact liquid [newtons-sec/m$^2$], $B$ = width of contact surface $A$[m$^2$] (usually proportional to this surface area) [metres], $v$ = sliding velocity [m/sec], $w$ = gap width [metres], and $\gamma$ = density of contact liquid [kg/m$^3$].

# The Regulation of Ward-Leonard Systems by Magnetic Amplifiers

By G. Alle and G. Fortpied. (From *ACEC Review*, No. 1, 1955, pp. 27-35, 16 illustrations.)

Most industrial applications for the speed regulation of electric motors concern d.c. machines. In such applications, the first problem is that of supplying direct current to the motor from an alternating-current network. This can be accomplished either by a rotary converter unit (e.g., Ward-Leonard) or by a static rectifier of the mercury-arc or the dry type.

The adoption of one or other of these solutions is based on criteria such as speed of response, efficiency, power factor, transmission of peak ratings to the network, recovery operation, installation costs, and maintenance charges.

The operation of the d.c. motor is determined by mechanical and electrical values, between which there are certain affinities. These values are respectively the rotational speed $N$; the torque $C$; the shaft power $P_m$; the voltage $V$; the electromotive force $E$; the current $I$; and the power taken from the network $P$.

When the flux is constant there is a direct relationship between the e.m.f. and the rotational speed, and between the armature current and torque.

The speed control of d.c. motors can be approached in two ways, i.e., control of the armature voltage and control of the flux, respectively. In the case of a machine with a constant flux, the control of the torque will be made by the armature current. Furthermore, for certain applications it may be necessary during transient operation periods either to reduce the initial starting period or re-starting period of continuous duty (time of response) or, on the contrary, to limit the strains of inertia during such periods by control of the acceleration.

## Control and Regulation Circuit

Control circuits are those in which an imposed reference value and a controlled value (output value of the installation) are constantly compared, the difference between these two values (error signal) being amplified in such a way as to excite the output elements. If the amplification is sufficient, the error signal will be sufficiently small, and the conditions of accuracy will have been met.

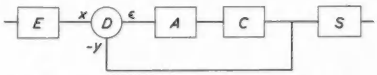



Fig. 1. **Basic diagram of a control circuit.**

The control circuit in principle comprises (Fig. 1) an input element $E$, which supplies the imposed reference value; a discriminator $D$, which compares the output value $y$ with the reference value $x$, so as to elaborate the error signal $\varepsilon = x - y$; an amplifying chain $A$; and the controlled elements $C$ supplying the output value $y$ utilized in $S$.

Such a circuit necessarily comprises two-way signal indications—the first in the input-output direction through the amplifier and the controlled elements, and the second in the reverse direction from the output value towards the discriminator. It is the presence of this return of the controlled value at the input of the amplifying chain which justifies the name of feedback circuit given to this secondary chain.

The control circuit becomes a regulator when the reference value is constant, the diagram being then arranged to maintain the output value constant, irrespective of the load conditions of the machine using it.

In the basic diagram of the speed regulation of a d.c. motor there are all the elements of a control circuit, i.e., a discriminator, an amplifier, and a controlled element connected together by a direct chain and by a feedback chain. The discriminator elaborates the difference between the imposed reference value and the output value, in this case the speed. This error signal is most easily established electrically, either from the difference between the two voltages or from the difference of the ampere-turns. For this it is necessary to measure the speed electrically. According to the accuracy required, this measurement is made by measuring the voltage at the terminals of the motor, assuming the flux to be constant; the same voltage diminished by the internal ohmic loss, always assuming the machine has a constant flux; the voltage at the terminals of a tachometer generator; and the frequency of a tachometer alternator.

As regards the imposed reference value, this will be provided by a potentiometer supplied at constant voltage, on which, of course, depends the accuracy of the regulation. This reference voltage can be stabilized with either electronic or magnetic amplifiers.

The amplification stages affected by the error signal may be of different types, i.e., rotary, electronic, or magnetic. The choice of one or other of these amplifiers depends on the ratings involved, the desired speeds of response, and the economic considerations, such as initial expense and maintenance.

It may be pointed out, however, that, although the magnetic amplifier is slower than the electronic, nevertheless it has a distinct advantage for industrial installations by virtue of its great sturdiness and its almost complete insensitivity to ageing. Furthermore, adequate calibration of the amplifier permits the reduction of its time constant, which can be further improved by utilizing a high-frequency a.c. supply (400 to 1000 cps).

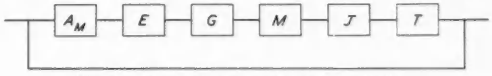



Fig. 2. **Basic diagram of speed regulation.**

The diagram in Fig. 2 shows in schematic form the various components of a system in which speed regulation is effected by control of the armature voltage of the motor or that of the tachometer generator. Basically, the system comprises the magnetic amplifier $A_M$, an exciter $E$, the generator $G$, the motor $M$, the total inertia at the motor shaft $J$, and the tachometer generator $T$. It is assumed that the motor is operating at constant flux. As each element is arranged to be able to supply all the succeeding elements, the accuracy of such a chain finally depends on the number of ampere-turns necessary to control the magnetic amplifier and those of the internal resistance of the control circuit. This permits determination of the error voltages and the accuracy for different speeds and loads.

Inversely, commencing with the accuracy required, it is quite easy to deduce therefrom the error voltage for a given type of circuit, the number of amplification stages required, and the characteristics of each amplifier.

## Stability of the Regulation Circuit

The regulation chain, as such, is naturally unstable. In fact, if an oscillation starts at the input of the amplification chain, it becomes progressively dephased, the longer it continues along the chain. If the total dephasing between input and output approaches 180 deg., as the output signal is negatively reintroduced at the input of the chain, this is joined to the initial oscillation and will maintain it, if it is of sufficient amplitude.

Of course, the best method of permitting stabilization of the chain would consist of reducing the amplification coefficient of the loop in such a way that the amplitude

of the signal reintroduced into the discriminator is insufficient to maintain the oscillation. Such a method, however, has the disadvantages of reducing both the accuracy and the speed of response, since it dampens the transmission of the low and high frequencies.

The solution to be sought should be one which does not damp the transmission of the low frequencies and corrects the dephasing angle of the natural oscillations of the system in such a way as to reject these oscillations onto the higher frequencies which can be damped. Such circuits, therefore, are both feedback circuits and phase correctors, and it is possible to group them into two categories, i.e., series corrector filters and anti-hunting transformers.

Of these two methods only the second is normally applicable in the power circuits considered here, the first method leading to prohibitive circuits both from the point of view of size and cost. It is, however, sometimes necessary to use both methods simultaneously, the correction network introduced in the anti-hunting circuit improving the operation of the latter.

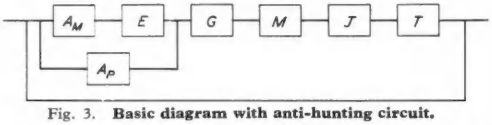



Fig. 3. **Basic diagram with anti-hunting circuit.**

The negative stabilizing feedback supplied by the anti-hunting transformer introduces into the amplifier control the derivative of the controlled value or of a previous signal of the chain. It is possible to obtain the same result by measuring the flux variations of the main generator by means of an auxiliary winding. The voltage taken at the terminals of this winding feeds a control winding of the amplifier. The diagram of the chain then becomes that shown in Fig. 3, where $A_P$ represents the anti-hunting circuit and its possible correction network.

### Control of Acceleration

Under slow variable duty, i.e., for very low frequencies, the voltage induced in the winding on the poles of the generator of the Ward-Leonard system is proportional to, and practically in phase with, the acceleration of the motor. Such is the case, for example, with winding engines which require about 20 sec to reach operating speed.

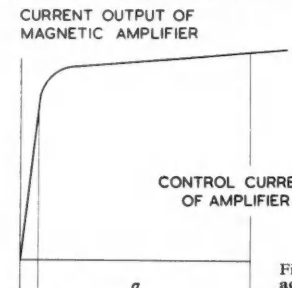



Fig. 4. **Principle of acceleration control.**

If the circuit is so arranged as to maintain the error signal constant during acceleration or deceleration periods $a$ (Fig. 4), but high before the signal indicating the amplifier is operating $b$, and if this error signal is compensated by a signal related to acceleration $c$, the amplifier having a tendency to function always in the operating zone, it is clear that $b$ is very much less than $a$, and $a$ = constant = $b + c$. Hence, $c \simeq a \simeq$ constant. Consequently, starting and braking operations will be made with controlled acceleration and deceleration.

The control current and the current of the stabilizing circuit are maintained practically constant during the entire duration of the transient phenomena, establishing a practically linear main voltage.

### Torque and Current Limitation

Although control of acceleration limits the current and torque peaks during transient periods, it may be necessary for certain applications to provide for a limitation of the torque and current protecting the mechanical section just as much as the electrical section of the installation, in case of a defect or faulty operation, e.g., jamming of the load, wedging of a moving part, or attempting to start with the brake on.

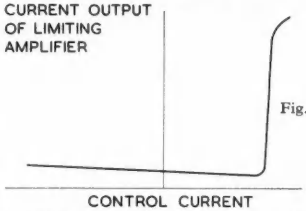



Fig. 5. **Limiting amplifier characteristic.**

The principle of current limitation consists of blocking every control as soon as the current reaches its imposed limit. It is therefore a question of introducing into the amplifier a signal which should remain nil, as long as the main current of the motor remains below a given value, but which entirely compensates the regulation signal as soon as the limit is reached.

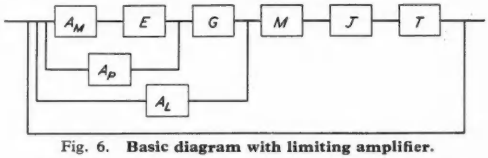



Fig. 6. **Basic diagram with limiting amplifier.**

The characteristic curve of the polarized magnetic amplifier satisfies these conditions, with the exception, however, of the magnetizing current, which is not always negligible, and the current output when the control is negative (Fig. 5). It is, however, possible to render this eddy current so small that its effect is negligible. The basic diagram is then as shown in Fig. 6, in which $A_L$ is the limiting amplifier.

## The Mechanism of Boron Hardenability

(*Concluded from page* 520)

points for shearing, such as imperfections of lattice, dislocations, or diffusion holes, will be remedied by boron atoms. As the boron atom, with its high mobility in austenite, is the largest among the interstitial solute elements, it is more likely to drop into these holes than carbon or nitrogen.

It is well known that nitrogen content in a solid solution generally decreases with an increase in carbon content. Therefore, an increase in carbon content (within the ranges of eutectoid composition) will be useful in producing favourable conditions for the adsorption of carbon atoms, due directly to the increase of its concentration and indirectly to the decrease in gas content in the solid solution. In the same way as in the case of boron, carbon hardenability will reach the degree equivalent to that gained by boron addition. Such a conclusion is the most probable in explaining the influence of carbon content on boron hardenability, i.e., the boron effect is inversely proportional to the carbon content and is essentially negligible at the eutectoid carbon content.

# Cavitation Attack in Ultrasonic Equipment

By L. A. Petermann. (From *Product Engineering*, Vol. 26, No. 9, September 1955, pp. 173-178, 8 illustrations.)

Cavitation damage is well known in turbines and pumps. At first, the surfaces are pitted only slightly, but the damage rate soon accelerates into deep attack, leaving surfaces with a very rough finish. Ultrasonic cavitation damage appears to be similar, but begins sooner and progresses faster. Where it takes several months of continuous operation in a turbine to show a given amount of damage, it may take only a few hours with ultrasonic cavitation. Some explanation of this accelerated damage is found in the repetition rate of the shocks. In a turbine, repetition rate may not exceed a few hundred or a few thousand shocks per second; in ultrasonic equipment repetition rates are several hundred thousand per second.

## Cavitation Phenomena

The presence of cavitation is evidenced by various phenomena, comprising a characteristic noise, especially loud at low frequencies and high intensities (amplitudes) of ultrasonic waves; the formation of bubbles of various sizes, especially at low frequencies; fluorescence of the liquid when cavitation is very intense; chemical effects; and abrasion and cavitation damage to submerged bodies and containers.

When each of the cavitation bubbles collapses, a shock wave is generated in which the peak pressure can attain values as high as 10,000 to 100,000 atm. The high repetition rate of shock waves, especially in ultrasonic cavitation, is held responsible for observed cavitation damage. If an abrasive is added to the liquid in which cavitation takes place, materials wear so quickly that, based on this principle, ultrasonic drills have found many industrial applications in the machining of hard materials.

A sonic or ultrasonic wave propagated in a liquid, if of sufficient amplitude, can produce cavitation. As each point in the fluid is traversed by the ultrasonic wave, the pressure is instantaneously equal to the algebraic sum of the amplitude of the wave and the static pressure of the fluid. When the wave amplitude is larger than the static pressure, there are intervals of time during which the pressure is nearly zero in the liquid and "pseudo-cavitation" may occur.

The reduction in pressure required to produce cavitation bubbles depends very largely on the purity of the liquid. If a liquid contains dissolved gases, microscopic gas bubbles, or dust particles, cavitation bubbles form easily and a reduction in pressure to the vapour pressure of the fluid is sufficient to produce "pseudo-cavitation." If the liquid under consideration is completely degassed and very clean, entire areas of the fluid seem to strain equally, distributing the stress of the reduced pressure, and localized bubbles do not appear. "Negative stresses," caused by the excess of ultrasonic pressure amplitude over the static pressure, as high as 200 or 300 atm, may be required to produce bubbles, this condition being termed "true cavitation."

## Ultrasonic Transducers

Barium titanate ceramic transducers, which are polarized ferroelectrics, function like piezoelectric transducers in that, when an electric field is applied across the polarized ceramic, there results a change in the dimensions of the transducer, roughly proportional to the strength of the electric field. If the applied field is an a.c. field, the dimensions of the transducer will change periodically. The dimensions and elastic properties of the ceramic determine the natural frequencies at which the transducer will vibrate in its different modes. As the frequency of the applied a.c. field approaches the natural frequencies of the different modes, the amplitude of dimensional change greatly increases.

The most important modes of vibration are radial, longitudinal, and thickness. The various modes of vibration are always coupled, so that motion in the longitudinal direction is always accompanied by a motion in the radial direction. As the transducer vibrates in its radial mode, a pressure wave is set up in the ring of fluid bordering the transducer. This high-pressure ring moves towards the central axis, increasing in amplitude as the radius and circumference reduce. Theoretically, an infinite pressure would be reached at the centre, if cavitation did not occur. However, cavitation bubbles form and absorb or reflect the ultrasonic wave back to the walls of the transducer. The variation of pressure across a cylinder is shown in Fig. 1. Peak values of pressure amplitude may reach

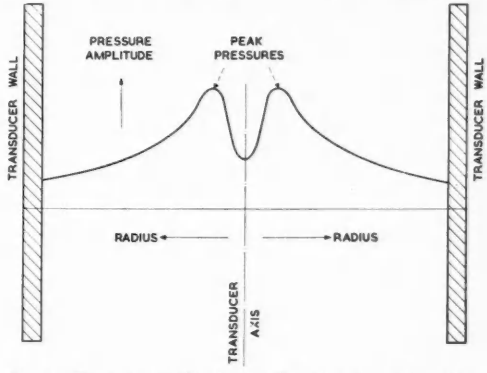



Fig. 1. **Pressure amplitude as a function of position along a diameter of a cylindrical transducer.**

very high values, frequently several hundred times the pressure amplitude at the cylinder wall. Cavitation bubbles collect in star-shaped or spider-shaped forms. These regions of intense cavitation undergo complicated changes of shape when the frequency is slightly varied near the resonance of the transducer.

## Testing for Cavitation Damage

The life of an ultrasonic transducer is usually very short if there is no special protection against cavitation damage. The following test procedure was used to devise suitable protection for the transducers as well as to determine the effect of cavitation on various materials.

As shown in Fig. 2, a 16-gal pyrex cylindrical container was used as a trough. The cooling system consisted of a coil of copper tubing immersed in the trough, with cold tap water as the coolant, permitting control of the equilibrium temperature during the test. The transducers were a Glennite piezoelectric ceramic, having a cylindrical shape of between 1½ and 6 in. o.d., and 1 to 6 in. long. They were firmly positioned on a rack immersed in the trough and connected to an electronic generator capable of delivering up to 400 W at any frequency between 10 and 1200 kc. On the same rack, a V-block was attached to hold the test rods in the cavitation field on the axis of the cylinder. A small lamp was arranged to direct light through the trough and through holes in the rack, making it possible to observe the cavitation field, cavitation spiders, and progress of damage on the metal rod. The whole system was enclosed in a soundproof cabinet to protect personnel in the test area, as both cavitation noise and low-frequency ultrasound can have a very painful effect on people in the vicinity.

The diameter of the rod tested was just large enough

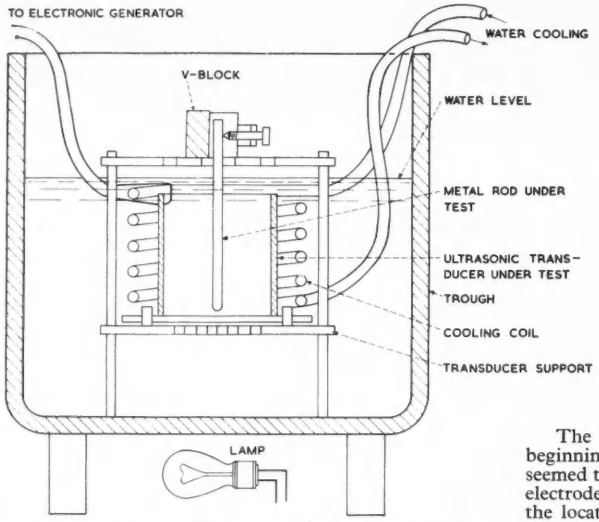



Fig. 2. **Arrangement of apparatus for testing cavitation damage to ceramic transducer coatings and rods of different materials.**

to place its surface at the points of peak pressure amplitude (Fig. 1). With a larger rod, cavitation would be less intense ; if smaller, the cavitation bubbles would act as a protective blanket, reflecting, diffusing, and absorbing sound energy.

*Choice of Frequency* :—Wavelength should be of the same order of magnitude as the diameter of the cylinder, since cavitation bubbles will diffuse and absorb ultrasound when the wavelength approaches the bubble size. It is advantageous, therefore, to choose a mode of vibration giving maximum radial motion of the cylindrical transducer and long wavelength. A 5-in. diameter transducer, with a length of 4 in., will resonate efficiently in the longitudinal mode (with appreciable radial coupling) at about 20 kc. At this frequency, the wavelength in water is approximately 3 in., much larger than the size of the average cavitation bubble. The screening effect of the bubbles is kept to a minimum, and the disturbance near the axis of the cylinder is restricted to a region of very small diameter.

*Test Results* :—Unprotected ultrasonic transducers operating in water will be seriously damaged after only a few hours of intense cavitation, as was shown by tests on a cylinder 6 in. in diameter and 5 in. high. The outside silver electrode had no special protection, while the inside cylinder was protected by a thin layer of special glaze. The cylinder was driven at 17 kc for a total of 250 hr in water. The temperature was kept at about 20°C. The water bath was changed approximately every 30 hr to remove the large amount of silver and ceramic particles suspended in the liquid by cavitation effects, and to keep the amount of dissolved gases in the water constant during the test.

After 27 hr, the unprotected electrode started to peel in large regions and, once initiated, damage to the unprotected electrode increased rapidly until, at the end of the test, only 25% of the total electrode area was left on the cylinder. The ultrasonic power output dropped considerably and the test had to be terminated. The inside electrode, protected with the glaze, suffered no apparent damage, although microscopic observation did reveal very tiny blue and black spots in the glaze.

Constant hammering between the ceramic cylinder base and the bottom of the trough, combined with cavitation, produced deep attack on the edge of the transducer. Electrical leads soldered to the electrodes were stranded copper wire connected to the electrodes by lumps of low-melting solder. The solder itself showed little damage, but the leads were severely attacked, both mechanically and chemically. Strong cavitation increased the oxidation rate of the copper, which was weakened and blackened, and strands were broken. The damage observed on leads was apparently of a different type from that of the transducer.

*Protection of Electrodes* :—A protection of glaze was found effective on large electrodes, as demonstrated by tests on a cylindrical transducer after 1100 hr of cavitation tests at 44 kc. Although the exposure was four times as long as in the first test and the ultrasonic intensity was about twice as large, damage to the electrodes appeared only on about 5% of the total area.

The glaze was not broken but " ground " away, beginning apparently on weak spots, and tiny holes seemed to be drilled right through the glaze to the silver electrode underneath. These holes may correspond to the location of small air bubbles in the glaze, since a perfect glaze could not be obtained. Some metallic compound from the silver electrode was brought to the surface of the glaze in minute, shiny spheres, and some other material was diffused under the glaze and formed a blue or black halo around the hole. With further tests, the metallic shiny spheres grew, the hole enlarged, and the blue and black diffusion regions extended until both glaze and silver were removed from the ceramic. Then the ceramic itself began to be destroyed at a slow rate.

Similar tests were performed on ceramic cylinders protected with thin layers of synthetic resins. The results were equally good, but the resins reduced the total ultrasonic output appreciably more than the glaze.

*Protection of Tranducer Edges* :—Adequate protection can be achieved by supporting the transducer on some resilient material, such as small wooden or rubber blocks. Thus, for instance, the cylindrical transducer just mentioned was protected in this way, and after 1100 hr of testing there were only a few microscopic pits on its edges.

*Protection of Leads and Connections* :—Solder itself, when applied in large enough lumps, is unaffected by cavitation. Leads may be covered with rubber or soft material, and protection is further improved by casting epoxy resin on the whole region where leads are attached to the transducer. Thus, complete electrical insulation is achieved, and the transducer can be immersed in water without electrical losses due to water conduction.

## Cavitation Damage to Metals

Various metal rods were submitted to intense ultrasonic cavitation at 33 or 44 kc for various exposure times, with the temperature kept at an average of 20° C. Attack was deeper and more rapid in the flaws of the sample. Cavitation damage was also more pronounced at spots where the surface was rough. These experiments show clearly that the cavitation " spider " has a very important part to play in cavitation damage to the solid rods. In many cases the shape of the cavitation spider, and especially its legs, determines the shape of damage areas of the samples.

No material can withstand the hammering of cavitation for long before real damage occurs. Damage from cavitation is not only mechanical destruction, but concurrent chemical action causes profound changes in metals such as steel, copper, beryllium-copper, and aluminium. The nature of these chemical reactions was not established. A glaze was found effective in extending the life of ceramic transducers by several thousand hours ; similar protection for metals may yet be developed.

# Filiform Corrosion

By A. Bukowiecki. (From *Schweizer Archiv*, Vol. 21, No. 5, May 1955, pp. 165-168, 5 illustrations.)

In recent years attention has been paid to a form of corrosive attack on metals which mainly takes place under paint coatings, first starting from individual points on the metal surface, then from all larger pores and defects of the paint film, and in time leading to the formation of threadlike corrosion paths which in places have a markedly tangled appearance (Fig. 1).

This type of corrosion is not particularly dangerous, because the corrosion paths remain on the surface of the metal, hardly affecting its mechanical properties, and do not destroy the paint surface. However, they are so noticeable that efforts towards their prevention are definitely desirable, at least when clear lacquers are used.

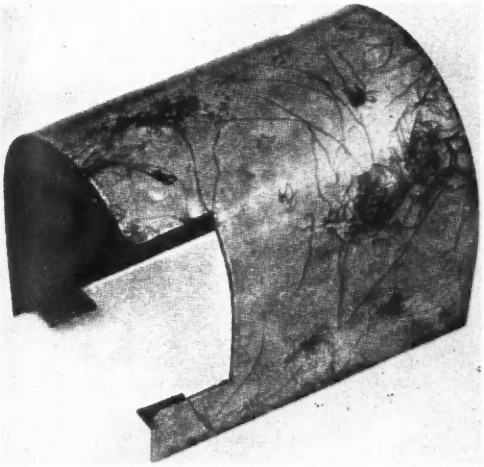


Fig. 1. **Filiform corrosion attack on a hygrometer housing, visible after removal of paint coating.**[2]

The first attempts to produce filiform corrosion artificially were described by Sharman,[1] who used polished steel plates coated with a transparent oil lacquer which was scratched after drying. To initiate corrosion, the testpieces were first held for a few days over a 5% solution of acetic acid and were then immersed in water. Soon after the immersion, filiform corrosion paths started to spread from many points along the scratches, advancing at a fairly constant rate of several centimetres per month. Each track consisted of a "head" filled with a blue liquid and having a rounded front, and a "tail" consisting of brown corrosion products and with a fairly constant width (0·1 to 0·5 mm). The characteristic boundary line, roughly V-shaped, between the head and the tail was fairly definite in most paths. Sharman has suggested that a quantity of acetic acid lodges in the head, promoting attack on the iron. This acetic acid, however, is consumed slowly and is therefore capable of travelling in the head over appreciable distances. This suggestion stimulated research, particularly in the U.S.A.

## Filiform Corrosion under Paint Films

(a) *Appearance of Corrosion Tracks* :—

Comprehensive studies of this subject were made by van Loo, Laiderman, and Bruhn,[2] who used metal panels coated with different paints and scratched after the paints had become dry. The panels were held for a few days over a 1% solution of acetic acid and were then transferred to acid-free air with a known moisture content. The starting points for the tracks were mostly along the scratches, but some tracks also spread from the less strongly protected edges of the test panels, from larger pores in the paint film, and from dust particles which had adhered to the surface of the specimens. It was also established that acetic acid is by no means essential for the initiation of attack; however, this method of producing corrosion was retained in the main experiments in order to obtain results as reproducible as possible, and to make direct

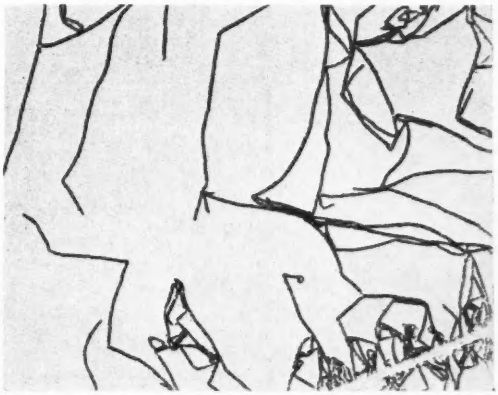


Fig. 2. **Filiform corrosion observed in laboratory tests.**[2] **(approx. ×3)**

comparisons easier. Fig. 2 shows clearly how the tracks start from the scratch in the paint film at the bottom right of the figure; the tracks are also most numerous in this area. A typical head is shown in Fig. 3.

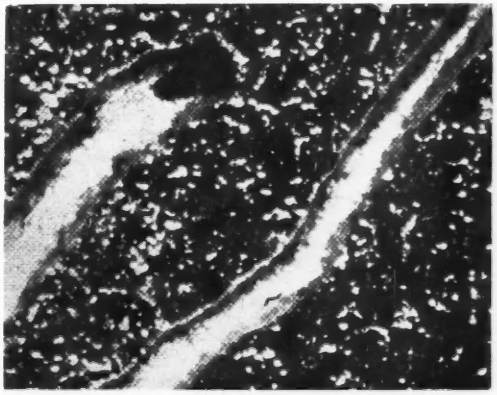


Fig. 3. **Head of a corrosion track.**[2] **(approx. ×60)**

These experiments have led to the following general conclusions :—

(1) Filiform corrosion under paint films occurs not only in iron, but also in magnesium and aluminium. It was not observed by van Loo and his co-workers in stainless steel, copper and its alloys, nickel, chromium, tin, and lead.

(2) There is no connection between the structure of the metal and the course of the corrosion tracks. These tracks cut across many grains without changing direction and without showing any tendency to follow the grain boundaries; on the other hand, they may sometimes follow deeper cuts in the metal surface.

(3) Formation of corrosion tracks was observed

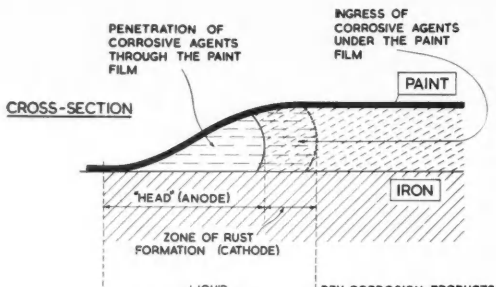



Fig. 4. **Diagram of paths of ingress of air at the head of a corrosion track.**

under various types of clear and pigmented coating media, i.e., those based on drying oils, oil-modified resins, phenolic resins, and vinyl resins. With pigmented media, however, the attack occurred only when a certain critical pigment concentration was not exceeded. The reason for this is that, above the critical concentration, the pigment particles are no longer completely covered by the binder, and the film rapidly becomes more porous.

(4) Under the experimental conditions chosen, conventional anti-rust pigments did not prevent filiform corrosion, and vapour-phase inhibitors mixed with the paint were also ineffective. Wash-primers did not prevent the attack, but tended to slow down its progress. A phosphate layer under the paint film prevented corrosion, provided that the layer remained intact.

(5) The action of micro-organisms is not necessary for the formation of corrosion tracks, as these appear even when the paint coatings contain such powerful antifouling agents as chlorinated phenols and cuprous oxide.

One of the most important observations of van Loo and his co-workers concerns the effect of air humidity on the formation of corrosion tracks under paint films. In their experiments with steel specimens, no corrosion, other than filiform corrosion, occurred with a relative humidity between 65 and 93%, the width and rate of advance of the tracks increasing with humidity. With 95% relative humidity, numerous round blisters filled with rust appeared in addition to the now very wide tracks. With a relative humidity of 100%, only rust blisters were formed but, when the humidity was below 65%, there was no corrosion at all. It was also observed that the growth of tracks was wholly arrested when they were transferred from air with more than 65% relative humidity to less humid air. The activity of the heads ceased and they turned yellow. When the specimens were returned to the original atmosphere, the heads regained their blue colour and the attack would recommence, though in a different direction. Furthermore, it is of interest to note that corrosion tracks do not normally cross each other. Should two heads happen to meet one another, the tracks will coalesce. If, however, the advancing head of one track should travel towards any point of an existing track, other than its head, it will be deflected, its angle of reflection being approximately equal to that of its incidence.

(b) *Mechanism of Filiform Corrosion :—*

It was found that each head and its adjoining zone of rust formation are markedly exposed to atmospheric corrosion (Fig. 4). Of all the oxygen in the air reaching the corroding iron surface, some passes through the paint film at the head of the corrosion track, but most comes *via* the scratch, taking a path under the paint film. The zone of rust formation is thus more strongly exposed to air than the head and becomes the cathode, while the head becomes the anode of a galvanic corrosion element. The existence of a potential difference between the iron surface in the head and the iron surface in the zone of rust formation has, in fact, been demonstrated by Slabaugh and Grotheer,[3] who, in addition, have shown that the blue liquid in the head is rich in iron compounds, while the liquid in the rust zone is more alkaline than that in the head. The reason for the formation of this blue liquid is that acid vapour penetrates the paint film and reacts with the surface, forming hygroscopic iron salts which absorb water vapour and form salt solutions.

With constant air humidity, the speed at which the tracks advance is mainly governed by the rate at which atmospheric water vapour penetrates the front surface of the head. A rise in air humidity is accompanied by an increase in the speed of advance and the width of the tracks and, when 95 to 100% relative humidity is reached, the tracks change into blisters. On the other hand, when humidity is low, the hygroscopic salts remain dry and no attack takes place.

No convincing explanation has yet been found as to why the boundary of the rust-formation zone is usually V-shaped; neither is it fully understood why, as a rule, the tracks do not cross each other.

As regards protection from filiform corrosion, the above studies have shown that the precautions necessary are identical with those taken against ordinary corrosion of a painted metal surface. Thus, the metal surface must be clean and free from hygroscopic substances before painting; the paint should be applied as soon as possible after the preparation of the surface and when the atmosphere is as dry as possible; and the film should not be broken by scratches or other defects. The study of inhibitors to be added to the paint to prevent filiform corrosion has so far not produced any practical results.

## Filiform Corrosion of Polished, Paint-free Metal Parts

Individual cases of formation of filiform corrosion on polished metal surfaces have been described in the literature.[4] Contributions on this subject have also been made by Hargreaves,[5] according to whom filiform corrosion of highly polished surfaces takes place only when there are particles of dust adhering to the surface. It is characteristic that corrosion tracks on polished surfaces are much narrower than tracks under painted surfaces, measuring about 0·0004 to 0·003 mm and therefore visible only under the microscope. Moreover, these tracks advance very slowly (0·2 to 0·4 mm per week), and change relatively easily into rust spots. Hargreaves does not discuss the mechanism of this corrosion, but it is reasonable to assume that it is much the same as that occurring under painted surfaces. It is quite possible that, even on very clean surfaces, there are traces of film-forming substances, or that such substances are carried by the dust particles settling on the surface.

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(4) Meeting of Corrosion Group, Soc. Chem. Ind.: *Chem. Ind.*, 1952, p. 1126.
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# Report on Geneva (III)

*Previous instalments, in our September and October issues, of our report on the International Conference on the Peaceful Uses of Atomic Energy, held at Geneva from August 8 to 20, 1955, dealt with power reactors, research reactors, and capital investment required for nuclear power stations. This concluding instalment covers the question of waste disposal, health hazards, and the potentialities of radioisotopes, particularly insofar as their industrial applications are concerned.*

## THE PROBLEM OF WASTE DISPOSAL

As the nuclear industry expands more and more towards centres of population, far more economical methods of disposal of radioactive wastes will become necessary. In this connection, it should be remembered that, in the utilization of fissionable material, in the controlled production of thermal energy power, or in a sudden explosion, highly radioactive products result. These products, called radioactive ashes, represent significant hazards, whether they originate in the production of fissionable materials, such as uranium or plutonium, within the reactor itself, or in subsequent chemical processing of spent fuel for the recovery of valuable materials. The industry produces such wastes with great variations in quantity, level of activity, toxicity, and physical form.

In general, high-level wastes in the atomic-energy industry are those requiring extensive shielding, to protect personnel handling them from exposure to harmful radiation. Such waste may contain as much as $10^2$ curies per litre. Fortunately, they are produced in much less volume than those of intermediate and low levels. It is difficult to estimate the percentage of total waste production which is of high-level activity, because of the variety in kinds of wastes. They might be as low as 0·5% and as high as 50%, depending upon the material being processed at a plant.

Intermediate-level wastes also require shielding and must be handled with care. The low-level wastes are those which, if decontaminated by a factor of $10^2$ or $10^3$, would approach permissible limits for human exposure. The range of their activity would be from $10^{-4}$ to $10^{-3}$ micro-curies per millilitre.

Radioactive wastes may be in liquid, gaseous, solid state, or some intermediate form. They may be combustible or non-combustible. The kinds and intensity of radioactive wastes are not detectable by human senses. These insidious characteristics make radioactive wastes especially dangerous, because they could be released to the air, the soil, or to surface waterways without detection. With proper instrumentation and radiometric analytical techniques, however, the constituents and characteristics of radioactive wastes may be determined with accuracy.

Important from the waste-disposal point of view are the long half-lives and known damaging properties to human tissues of certain of the isotopes. Regardless of what is done to or what use is made of a radioisotope, it will continue to give off radiation at its natural decay rate. As long as its radioactivity is in excess of permissible limits of exposure, a radioisotope is a potential hazard. These unique properties of radioactive wastes place more than average responsibility on those responsible for their disposal and also on officials charged with the protection of public health and natural resources.

Radioactive waste products have numerous sources and must be evaluated carefully before wastes are treated and disposed of. This is especially true as use of nuclear energy by competitive industry expands and reveals the true cost of waste treatment and disposal as a substantial item for consideration. Current practices, while adequate, are costly and necessarily conservative. Special emphasis is being given to environmental problems in the disposal of these wastes, because, as private industry uses atomic energy, its plants must be reasonably near the populations served.

The high-level wastes originate principally, but not entirely, from the chemical processing of fuel from nuclear reactors, in order to recover unburned portions. Associated with the irradiated fuel are many fission products with radioactive half-lives varying from seconds to millions of years. Such products have fixed rates of radioactive decay which never vary. Customarily, the irradiated fuels as removed from a reactor are stored under water in order to permit decay of the short-lived fission products. Storage from 90 to 120 days is desirable, but processing within shorter periods may be necessary. With shorter periods of storage, problems of handling and disposing of the product are intensified.

These high-level wastes contain the entire spectrum of fission products formed when the uranium atoms are split. The waste solutions contain various salts and acids besides the fission products. The manner in which the uranium is utilized in the reactor, whether in solid or liquid form, determines the particular chemical separation process used. It determines likewise the physical, chemical, and radiochemical properties of the waste solution ensuing.

### Methods of Waste Disposal

Some methods, among others, of waste disposal are as follows :—

*Chemical Processing :—*

Improvements have been consistently made in the chemical-dissolving, extraction, and stripping processes and facilities. Most important is the effort to remove these highly active wastes at the point of origin —where the volume is small—rather than to permit them to mix with and contaminate a high-volume system where decontamination is very expensive. Formerly, nitrogen-oxide fumes and iodine vapours arising from fuel-dissolving operations were released to the atmosphere through high stacks. Now, these fractions of gaseous effluents are removed by scrubbers and by the use of chemical reaction involving silver nitrate. Highly radioactive particulates, varying in size from 50 microns to fractions of a micron, are now being removed in deep-bed sand and glass-fibre filters of high efficiency. Glass-fibre filters (99·95% removal efficiency for 0·3-micron particles) are manufactured commercially. At present, these filters will handle gaseous effluents up to 600° F. Similar media to perform satisfactorily at 1500° F are being developed.

Prior to discharge of liquid wastes to tanks and in an effort to concentrate radioactivity in as small a volume as practical, coprecipitation processes in series are sometimes used. The supernatants of low activity are released to the ground, usually through cribs and reverse wells. Concentrates are buried in underground tanks. A disadvantage in coprecipitation is the volume of sludge which must be handled. Evaporation has also been used extensively to reduce the volume of liquid wastes, both of high and intermediate levels of activity. At costs ranging from 5 to 70 cents (4½d to 5/-) per U.S. gallon, it is an expensive process for low- and intermediate-level wastes. Evaporation can be used to give a decontamination factor of $10^5$ and even higher. High-level radioactive wastes also can be reduced in volume by ion-exchange methods. They are quite expensive, however, and the problem of disposal of the highly active resins remains. In all cases a balance must be arrived at between the overall decontamination value of the process, the volume of byproduct wastes resulting, and the cost of the process in relation to other waste-disposal possibilities.

*Storage Underground in Tanks :—*

Storage of highly radioactive wastes in large underground steel and steel-and-concrete tanks as practised at present is a real problem. In the first place, it is costly, the capital cost varying from $0·35 to $2·00 (2/6 to 14/3) per U.S. gallon of capacity. The thermal heat which results from gamma radiation is very high. In order to protect the tanks from deterioration by corrosion, excess heat must be carried away by a cooling system. To detect leakage from these tanks a system of drains is installed around them, leading to a monitoring pit. The true life of these tanks is unknown. It is certainly much shorter than the length of time some of the long-lived radioactive materials will continue to be hazardous. It is not a simple task to remove entirely the high-level radioactive material after it has been stored in a tank over an extended period. Steam-jetting is one method in use. Although the costs of tank retention are high, the method has one advantage in the present stage of only limited knowledge, i.e., that the wastes are under control.

Environmental factors, such as the capacity of soils in the vicinity of these tanks to absorb radioactive wastes, should they leak, and the rate of movement of such wastes through the soils, especially to underground sources of water supply, are extremely important. The possibility is under study of fixing high-level radioactivity in wastes by natural or prepared soils or by chemical compounds, so that they may be disposed of safely by burial or underground storage with little likelihood of release to the environment. Removal of more hazardous and long-lived radioisotopes, such as $Sr^{90}$, $Cs^{137}$, and $Ce^{144}$, before discharge to the tanks or to the soils, would reduce environmental hazards, provided that they were adequately fixed or retained for disposal.

*Ocean Disposal :—*

Proposals have been made that high-level radioactive wastes be disposed of by dumping into the ocean in deeps far off shore, as is now practised for disposal of some miscellaneous industrial wastes. The cost of shielding and transportation militates against this method for high-level wastes for many present and future plant locations. Other factors which make ocean disposal of such wastes of doubtful value are the high levels of radioactivity and heat in these wastes, the inability of recovery, and uncertainties as to the effect of these wastes on other uses of the ocean in the service of mankind.

The whole problem of ocean disposal is now under careful study, and until oceanographers provide a greater assurance of the ultimate safe fate of high-level wastes dumped into the ocean, the practice to withhold such materials will be continued by the U.S. Atomic Energy Commission. The uncertainty regarding the safety of sea disposal stems from the fact that the physical, chemical, and biochemical behaviour of the ocean cannot be satisfactorily predicted. Rates of circulation, diffusivity, and turnover have not been firmly established. Even the instrumentation for so doing is not at hand.

Low- and intermediate-level radioactive wastes from the industry are being disposed of in selected dumping areas in the Atlantic and Pacific Oceans. The wastes are mixed in concrete and held in reinforced steel drums. Studies reveal that the cost of disposing of intermediate- and low-level wastes in oceans, including packaging, handling, and disposal, vary from $0·30 (2/2) per pound for installations within reasonable shipping distance from New York Harbour and to $0·80 to $1·00 (5/9 to 7/2) per pound for wastes from installations in the vicinity of San Francisco. On the East Coast of the U.S.A., wastes totalling from 20 to 30 tons per year are disposed of to the ocean and on the West Coast 4 to 5 tons. The difference in amounts is reflected in the costs.

*Incineration :—*

Combustible radioactive material, such as paper, animal carcases, pieces of wood, or cardboard, may be disposed of by incineration. Incinerators, each different, were built to serve the AEC research and development areas—Los Alamos Scientific Laboratory (LASL), Argonne National Laboratory (ANL), and the Knolls Atomic Power Laboratory (KAPL). Each unit was provided with equipment for a high degree of clean-up of the products of combustion, resulting in radioactive solutions to be disposed of, as well as the incinerator ash. The LASL unit has given considerable difficulty and is being remodelled. The ANL incinerator has performed satisfactorily at relatively high costs of $2·68 (19/-) per cubic foot, including overhead and amortization charges.

The KAPL unit was a pilot plant and used oxygen to complete combustion. Its costs were also high, about $5·00 (35/-) per cubic foot. Realizing the need for satisfactory and economical incinerators at its installations and also at research institutions working on problems of the industry and using radioisotopes, the AEC contracted with the Bureau of Mines for development of a suitable unit. After many months of study of combustion parameters, designs and specifications of two incinerators having capacities of 25 and 200 pounds per hour, respectively, are being completed. Each uses a tangential overfeed air-supply system in the combustion chamber, resulting in such a high degree of burn-up that all that is required for treatment of the gases of combustion is an inertia-type separator for the larger particulates, followed by a high-temperature, high-efficiency, all-glass fibre filter.

*Baling :—*

At KAPL wastes of the kind formerly incinerated are now being baled, using an electric baler. The bales are stored uniformly and then shipped by rail to a storage area, where the bales are stored, together with certain radioactive sludges and miscellaneous obsolete equipment and material which cannot be reclaimed or salvaged for scrap, because of radioactivity.

*Burial :—*

Burial of radioactive wastes, particularly solids, is widely practised at the larger AEC installations, such as the Hanford Works, the Oak Ridge National Laboratory, the National Reactor Testing Station, and at the Los Alamos Scientific Laboratory. The selection of burial grounds is made with the assistance of a qualified geologist, to take adequate account of (*a*) the characteristics of the soil to retain radioactivity, (*b*) the rate of release of waste from the burial area, (*c*) the elevation at and the rate of movement of ground water from the area, (*d*) the effect of release in contamination of the ground water, and (*e*) the distance to downstream users of ground water. Burial has the advantage of low cost and effective shielding. If movement of water through the soil is slow and the distance to ground-water users large, a very substantial decay of radioactivity may take place before any source of water supply is affected. In the case of long-lived wastes, however, serious consideration must be given to the possible effect of any burial practice on the natural resources of the area. It is not likely that in movement through the soils there would be much lateral spread of contaminants released from a point source. Research as to selective absorption of radioactivity in soils and movement through them under various conditions is in progress.

*Deep Wells :—*

Consideration also has been given to the possibility of disposal of radioactive-waste solutions by discharge to abandoned oil and gas domes through deep wells. The economic aspects of the problem rest on the cost of shielding and delivery to the chosen well site. This method of disposal is being explored because it has obvious advantages. The feasibility of the use of

abandoned mines and caves as storage places for high-level radioactive wastes is also being considered.

The use of any subterranean method of disposal of high-level wastes will require the most intensive scrutiny by experts working in collaboration with specialists in the nuclear-fission industry. Although, in the United States, a number of areas is underlain by geological formations possibly suitable for the disposal of high-level wastes, it is agreed by experienced geologists that the use of such formations for the purposes discussed should be deferred until these formations have been further explored and evaluated. In such explorations and studies, the baffling problems, among others, of heat dissipation and general thermal behaviour will require detailed attention and diagnosis.

### Future Problems

Most observers are of the opinion that the next 25 years will produce major developments in the production of nuclear-fuel power. Whether optimistic or conservative views on these prophecies or hopes are shared, one conclusion is clear:—The disposal of reactor and fuel processing wastes may well be one of the major controlling factors in determining the extent of the use of power reactors competitively with other sources of fuel for energy production. In this connection, some hold that the resulting total of fission products will be prodigious. On the other hand, it has been estimated that a world consumption of nuclear fuel of 1000 tons is unlikely to be exceeded in the foreseeable future, as this level of nuclear energy would be equivalent to twice the present world coal production of 1500 million tons. If, therefore, it is possible to dispose, economically and without immediate or subsequent danger, of a quantity of fission products of this order, there should be no need to impose later restrictions on the expansion of nuclear industries because of the fission-product nuisance. Nevertheless, to dispose of these materials will undoubtedly challenge the ingenuity and imagination of the scientist and industrialist. The economics of packaging, transporting, storing, treating, and releasing these materials at some future time are still a source of great worry, and the return of these wastes to nature must be undertaken with caution.

In conclusion, it may be said that the problems in waste disposal for the atomic-energy industry are many and, although control of such waste is at present adequate, it is expensive. As the industry expands, especially in the field of power, less expensive methods will be required, if atomic energy is to compete favourably in cost with other fuels. At the moment, for maximum protection of the public, high-level radioactive wastes are now stored both on and off site under rigid supervision. Disposal, in its orthodox sense, as applied to familiar industrial waste products, is not yet at hand.

## RADIOLOGICAL HAZARDS FROM NUCLEAR REACTORS

The possible consequences of a large-scale release of radioactivity from a nuclear reactor in the event of accident has long been recognized as an important factor in the development of nuclear power. The problem has become more pressing with the rise in total power and with the very high heat ratings in some of the designs now envisaged. The selection of suitable sites for nuclear power plants calls for an assessment of the radiological hazards from an escape of radioactivity and for the satisfactory limitation of the quantities of activity which might be released in the event of accident.

Direct experience has fortunately not yet shown the extent of the radiobiological effects of a massive release of radioactivity from a nuclear reactor. In the reactor incidents which have been reported so far, the releases to the atmosphere and the consequent radiological effects have been trivial. Reliance must therefore be placed on theoretical estimates, though realistic calculation is difficult in view of the large number of imponderable factors. The validity of the results may be judged by applying similar reasoning to other hazardous materials for which long experience is available. An attempt has therefore been made to estimate the hazard ranges of a release of activity and to compare these with industrial experience in the large-scale handling of the toxic gases, chlorine and phosgene.

### Biological Importance of Various Radiation Levels under Accident Conditions

Levels have now been agreed internationally for the permissible contamination of air and drinking water for consumption over a lifetime by persons exposed occupationally to radioactivity, and safety factors have been introduced in evaluating these figures to ensure that no detectable injury will result. For the present purpose, however, it is required to know the levels appropriate to a single emergency, at which definite injury is likely or at which drastic action, such as evacuation to avoid such injury, must be taken. The exposures envisaged would occur only in the event of a major accident, and such events must necessarily for economic reasons be extremely rare.

A cloud of radioactivity released to the atmosphere may be effective biologically in two ways, i.e., by direct biological effects of beta and gamma radiation and inhalation of the activity during passage of the cloud, and by indirect biological effects due to deposition of the activity onto crops, herbage, drinking-water sources, and ground. It should be remembered, too, that normal habitation also involves the risk of ingesting deposited activity and particularly the bone-seeking isotopes, such as $Sr^{89}$.

The following criteria are therefore suggested for considerations of siting and the possible need for evacuation of members of the general public in the event of a nuclear-reactor accident:—

(*a*) The exposure to gamma radiation should be limited to not more than 25 roentgens in three weeks and 60 r in three months.

(*b*) The inhalation or ingestion, due to continued occupation of a contaminated area, should not exceed 30 micro-curies of $Sr^{89}$. This level allows for the other associated bone-seeking fission products.

(*c*) The accumulation in the body of long-lived activity, such as $Sr^{90}$, should not be allowed to build up to a value exceeding the recommended peace-time permissible body burden for occupational exposure (1 $\mu$c for $Sr^{90}$ and 0·04 $\mu$c for $Pu^{239}$), since, if greatly exceeded, the activity would probably lead to serious incapacity in later life.

### Consequences of an Accident

In the event of a reactor accident, there will probably result a release of radioactive material from the reactor. Operating personnel may be seriously injured or perhaps even killed. The reactor itself may be damaged beyond repair or recovery. The reactor building and its associated equipment are very likely to be heavily contaminated and, indeed, it may not be possible to clean up the building sufficiently to put it into operation again. Design of the building, so that possible clean-up operations are as easy as possible, is desirable. Smooth, clean surfaces, perhaps clad in stainless steel, would make clean-up operations easier. Finally, radioactive materials can escape from the reactor site altogether. Fission products may be carried in the wind and spread over adjacent populated areas, constituting an acute hazard. Radioactive material may escape into the ground and be carried by the percolating ground water to adjacent rivers or other water supplies. Although a great deal needs to be known about the character of radioactive material which might escape from a reactor,

whether it is in large or small particles, whether it is indeed gaseous, whether it would rise high into the air or seep slowly along and into the ground, nevertheless, some notion of the possible spread of the hazard could be obtained by study of the meteorology and hydrology at the reactor site. It is desirable, for example, that the prevailing wind blow from the reactor to uninhabited areas. It is also desirable for the reactor site to be located away from a main watershed. From the point of view of the hazard alone, it is, of course, desirable to have the reactor site far from populous or vital industrial areas. It will not always be possible to obtain this remote location and still obtain economic utility from the reactor. For this reason, the importance of safe reactor designs, the development of contained fuses to minimize the possibility of a runaway accident, and the use of gas-tight containing vessels and buildings, are emphasized.

In the event of a reactor accident, assuming that good luck prevails and no one is killed, it may nevertheless be necessary to evacuate a large city, to abandon a major watershed, and very probably it would be necessary to make the reactor site itself a forbidden area for some years to come.

Nevertheless, it should be understood that accidents must necessarily be infrequent and, provided that they do not involve the release of more than a few tenths of a megawatt equivalent of fission products, remote siting of reactors should be unnecessary. It is considered that this degree of containment can be maintained by adherence to sound principles in the design, construction, and operation of nuclear plant. It is therefore concluded that the satisfactory siting of high-power reactors with suitable engineering safeguards will not present an insuperable problem in the development of nuclear power.

## RADIOISOTOPES

Radioisotopes are exceedingly abundant and widely useful byproducts of nuclear reactors. Reactor radioisotopes have now been distributed extensively for nine years and their use has grown rapidly. Nevertheless, they are still far from attaining their vast worldwide potential for gaining new knowledge and improving health and welfare.

As has been true for other nuclear developments, the concepts, discoveries, and instrumentation which have led to the production and use of radioisotopes have been international. It is interesting to note that uranium has had both a singular and rejuvenated role as a source of radioactivity. Uranium first brought to man's attention in 1896 the phenomenon of radioactivity, in itself a form of nuclear energy (although not then recognized as such); now, almost 60 years later, it provides by means of the uranium chain reaction a tremendous source of both useful energy and a broad array of new radioactive species. Uranium, source of many useful natural radioisotopes, has thus also become through the reactor the major source of the more numerous and more widely applicable man-made radioisotopes.

### The Power of Isotopes as Tracers

The sensitivity of the isotope tracer technique depends on detection of the isotopic label after dilution with other atoms of the same element. Dilution with atoms of dissimilar elements can usually be eliminated, if necessary, by chemical separations.

If a stable isotope with a natural abundance of about 1%, such as $C^{13}$, were concentrated to 100% abundance, it could be diluted only about $10^4$ times with normal carbon and still be detected. This is, of course, suitable for some experiments, but is a serious limitation for many. A stable isotope with a higher natural abundance would have a smaller limit of possible dilution. Deuterium, with a natural abundance of only 0·015% and obtainable almost isotopically pure, presents a most favourable stable isotope tracer. In this case, using a mass spectrometer, a dilution with normal hydrogen by almost $10^6$ times is detectable, although with difficulty.

The dilution attainable with a radioactive tracer depends on available activity per gram of the element, efficiency of the detector, and reliability of detection above the natural radiation background. For example, "carrier-free" or 100% $P^{32}$ has an activity of about $2{\cdot}9 \times 10^5$ curies/gm or $6{\cdot}4 \times 10^{17}$ disintegrations/min/gm. With ordinary Geiger-counter methods it is easy to detect less than 20 counts/min above background or around $10^{-16}$ grams of $P^{32}$. If the sample is diluted with stable phosphorus, self-absorption will reduce the amount detectable. However, self-absorption is greatly reduced and counting efficiency increased by new methods, where the radio material is placed inside a liquid scintillation medium or gas counter. Using the latest low-level counting techniques, in which the natural radiation background is minimized by shielding and anti-coincidence methods, it is possible to measure radioisotope samples containing only a few disintegrations/min/gm. For carrier-free $P^{32}$ this would in theory permit a dilution with ordinary phosphorus of about $10^{17}$. Even if this dilution is "theoretical," it is obvious that $P^{32}$ can be readily detected after tremendous dilution. Many other useful isotopes, such as $I^{131}$, have very high carrier-free activity and can be detected with comparable sensitivity.

In case the element has a radioactive isotope in nature, as for example tritium ($H^3$) and $C^{14}$, this activity becomes an inescapable part of the natural background for this element. For "living" (biosphere) carbon the activity is about 13 disintegrations/min/gm, whereas for carrier-free $C^{14}$ the activity is about $10^{13}$ d/min/gm. Theoretically, therefore, $C^{14}$ could be traced after dilution in "living" carbon almost a million million times. Tritium has an activity of about $2 \times 10^{16}$ d/min/gm, and its natural specific activity is extremely minute; consequently, it can be traced through an even greater dilution than $C^{14}$. Such sensitivities of detection are millions of times greater than for any other means.

In addition, the isotopic labelling technique can be unquestionably specific. An isotope of an element is chemically identical with the element, except for a small "isotope effect" in chemical reactions affected by differences in isotope mass. The isotope effect is demonstrated by altered reaction rates, but not by a qualitative difference in mechanism of reaction. Difference in reaction rates is considerable only for isotopes of great mass difference, such as those of hydrogen, but is demonstrable for isotopes of carbon. The effect can be taken into account, however, when it effects quantitative experiments.

Several criteria must be met for an isotope to serve as a "perfect" tracer. The dose of radiation or amount of chemical added must not affect the reaction studied. Also, the isotopic label must be in the proper chemical state or affixed in the proper molecular location. These criteria, however, are in general readily satisfied.

Available counting techniques permit almost any tracer experiment to be accomplished with amounts of radioactivity very much less than those which might affect the system. To avoid adding chemically toxic amounts of the tracer, it is often necessary to have very high specific activity material. Radioisotopes made by transmutation or fission are obtainable almost carrier-free; hence, specific activity is generally no problem. Radioisotopes produced by neutron absorption may have to be irradiated in a high-flux reactor to meet this criterion. Reactors with fluxes in the range of $10^{13}$ to $10^{14}$ neutrons/cm$^2$/sec produce sufficiently high specific activity in even the most toxic elements.

Techniques of multiple labelling with isotopes provide additional means of achieving specificity in tracer experiments. Different portions of a molecule can be labelled simultaneously with two or more

isotopes. Double or even triple labelling of organic compounds is accomplished with such isotopes as $H^2$, $H^3$, $C^{13}$, $C^{14}$, $N^{15}$, $P^{32}$, and $S^{35}$. Such labelling permits simultaneous tracing of individual portions of a complex molecule, thereby checking molecular decomposition, as well as eliminating the question of exact reproducibility of experiments.

It is usually possible to identify positively a radioactive isotope by its radiation and/or half-life. With proportional or scintillation counters and pulse-height discrimination circuits, it is often possible to use several radiotracers simultaneously in an experiment and to count them separately without chemical separation. Furthermore, with such discrimination equipment, it is possible to carry out accurate neutron activation analysis. The material to be analysed is irradiated in a reactor, and the induced radioactivities are differentiated. This technique can identify parts per million or even million million of certain elements. The method has, however, limitations. A high flux of neutrons is required; the unknown element must be suitably activated; and too many radioisotopes with similar radiation characteristics must not be produced simultaneously.

Other special powerful analytical procedures are possible with radioisotopes. Mention should be made of various types of " isotopic-dilution " techniques. An isotope-labelled compound of known isotopic ratio may first be added to a system containing the unlabelled compound. Then, after thorough mixing, an isotopic analysis of the altered ratio for an unknown portion of the total gives the dilution of the isotope label and thereby a quantitative measurement of the total amount of the compound originally present. This technique is useful when the system is very large or the compound cannot be quantitatively extracted.

A similar isotope technique is used to determine the success of chemical purification. The desired pure compound is properly synthesized with a radioisotope label. This is then mixed homogeneously with the compound being purified, and the specific activity determined. If, after repeated purifications, the specific activity of the compound remains constant, maximum purification has been achieved with the procedure. Use of this technique, together with chromatographic, electrophoresis, and ion-exchange separations, reveals constituents below conventional criteria of chemical purity.

Autoradiography should also be noted as a sensitive and detailed detection method for radioisotopes. It uses a photographic emulsion to obtain a picture of the distribution of radioactivity, for example, detailed location of radiomaterial in tissues or cells, or in the grain structure of metals. With fine-grain nuclear emulsions, resolution can be achieved down to about 5 microns. A new high-resolution wet-process autoradiography uses a very thin layer of sensitized silver bromide capable of giving resolution down to one micron. Although this is far from the resolution obtainable with good microscopes, when combined with the tracer technique it provides information not obtainable in other ways.

Great versatility is possible in the labelling of materials with isotopes. Useful radioisotope tracers can be produced for most elements. Fortunately, for those elements having radioisotopes with half-lives too short for tracer work, such as nitrogen and oxygen, it is possible to use the concentrated stable isotopes ($N^{15}$ and $O^{18}$). In a few cases, such as fluorine and copper, however, stable isotope tracing is not feasible, and the radioisotope also has a limited half-life. Aluminium was in the latter category, but recently a long-lived isotope $Al^{26}$ has been produced by cyclotron bombardment of magnesium and, although obtainable only in low yield, may provide a tracer for this important element. The overall situation for tracing elements is thus most fortunate. Luckily, also, most of the important radiotracers can be made with a reactor.

Furthermore, methods have been devised for synthesizing a large number of isotope-labelled compounds, either by chemical or biological means. Over 1000 labelled compounds are now readily available. These include biochemicals, pharmaceuticals, and industrial chemicals. Techniques have also been devised for labelling a wide variety of organisms such as blood cells, bacteria, viruses, and higher organisms. Fabricated materials, such as piston rings and machine tools, can be activated directly by irradiation in the reactor. The total result is a very large number of elements, compounds, materials, and organisms which have been made radioactive for tracer studies.

The radiotracer technique thus has the combined power of tremendous sensitivity, unquestioned specificity, and wide versatility. Such a great extension of power of observation supports the prediction that isotopes may become a scientific tool as commonly and as widely necessary as a microscope.

## Scope of Radiation Sources

In addition to their use as tracers, radioisotopes have another broad and important category of application as sources of radiation. For this use chemical identity is not the major interest, but rather the character and output of radiation. Here also radioisotopes are very versatile. They provide alpha, beta, gamma, and in some cases X-ray sources. Also, by secondary means they may provide X-ray and neutron sources. The range of available radiation energies and half-lives is broad enough to cover requirements for a large variety of practical uses.

Reactors provide radioisotopes in far greater intensities and at much lower cost than do natural sources or particle accelerators. The tremendous production capacity of the reactor, while very desirable to produce isotopes even for tracer uses, is absolutely essential for wide-scale application of radioisotopes as radiation sources. For example, the activity of gamma-ray-emitting isotopes now used in radiography totals thousands of curies, and for teletherapy of cancer the ultimate use will total hundreds of thousands of curies. Large-scale sterilization of foods and drugs would require millions of curies.

The only reactor-produced alpha-ray emitter now used widely in industry is $Po^{210}$. It is not only useful as an alpha source, as in self-luminous compounds and static eliminators, but is extensively used with beryllium for neutron sources. Reactor production far surpasses the normal supplies of natural polonium and at much less cost. Po-Be sources containing 50 curies or more per source are readily available. The yield of neutrons averages about $2{\cdot}3 \times 10^6$ n/sec/curie. Many Po-Be neutron sources are used for neutron " logging " of oil wells and other techniques which depend on neutron reflection from hydrogenous material. Other alpha-ray emitters, such as plutonium-239, can be produced by reactors. Some of these would have certain advantages over polonium, particularly in longer half-life, but their applications as sources await further development.

Many beta-ray emitters can be and are produced in reactors. Thus, for instance, $Sr^{90}$ is extracted from uranium-fission waste and $Tl^{204}$ is produced by reactor irradiation of thallium. These two beta emitters find wide industrial use at present, because of the combination of long life and energetic radiation. For some industrial applications, however, the low-energy beta rays of $H^3$ are useful. Because $H^3$ can be produced cheaply, is comparatively safe to handle, and has a desirable half-life, it should come into extensive industrial use.

In the same way, many important gamma-ray emitters can be produced in the reactor. For biological and medical purposes, including therapy, the short-lived

isotopes, such as $Na^{24}$, $I^{131}$, and $Au^{198}$ are extremely useful gamma-ray emitters. $Co^{60}$ and $Cs^{137}$ have many industrial uses, owing to their long life and high energy radiation, while $Tm^{170}$ is valuable for its very low-energy gamma-ray output, though its half-life of 127 days calls for frequent source replacement.

Most gamma-ray radioisotopes also emit beta rays. However, for most uses the beta rays are of no consequence or can be filtered out. $Fe^{55}$ is an isotope with no beta rays and gives soft manganese X-rays with special applications.

It should also be noted that beta rays can excite X-rays (bremsstrahlung) and that low-intensity X-ray sources can be obtained from high-intensity beta-ray sources. Lack of long-lived low-energy gamma-emitting isotopes has prompted the development of such beta-ray-excited X-ray sources. These sources can have a long life and a wide range of energy spectra; consequently, many industrial applications can be expected.

## Versatility of the Principles of Utilization

The tremendous variety of uses of radioisotopes stems from three very versatile basic principles applicable to radiations, i.e., (1) radiation affects materials, (2) materials affect radiation, and (3) radiation traces materials.

The first of these three principles, the use of radiation to affect materials, is the least exploited at present but is expected to play a large role in the future. Although radiation can have many different effects on materials, these effects all result from ionization or excitation of atoms or molecules. Thus, the radiation from radioisotopes is applied to produce ionization of air in static eliminators, excitation of phosphorescent light sources, destruction of bacteria in foods and drugs, activation of chemical reactions, polymerization of organic materials, alteration of material strength and conductivity, gene changes, and therapeutic results in patients.

In the second principle of use, radiation is directed at or through a material to gain information about the material. Here, the requirements are a radioactive source, the material, and a detector to record the radiation transmitted through or reflected from the material. All interactions of radiation with materials lower its energy or remove part of it from a beam. The thickness of a material, its density, atomic number, and atomic structure have different effects on different radiations. Therefore, much can be learned regarding these properties by observing their effects in absorbing or reflecting radiations.

The major applications of this principle are industrial and clinical radiography, thickness and density gauging, and analysis by radiation penetration. Other important uses include liquid-level gauging and applications where an object is revealed by its effect on a beam of radiation. The principle is also applied to industrial sorting and packaging problems.

In applications based on the third principle, the radioisotope is incorporated in or carried by the substance of interest. This substance can then be located or traced, or parts of it measured quantitatively. Radiomaterial can be traced in bulk, as in locating markers, determining fluid flow, following motion of material, detecting leaks, and measuring wear and abrasion. Also, radioisotopes as tracer atoms are used to study all kinds of chemical, physical-chemical, and biochemical problems. In technology, tracer uses include studies of corrosion, diffusion, detergency, catalysis, and the kinetics and mechanisms of reactions.

It is obvious that each of these principles has much versatility in application. They provide a wide spectrum of uses, covering many fields of technology, as well as varieties of industrial materials, processes, and products.

## Specific Illustrations of Usefulness

Luminescence, an effect of radiation on special phosphor materials, provides self-luminous material for safety marking in aircraft, mines, and public buildings, for low-level illumination, and for standard light sources. Isotopes used for the purpose include polonium, tritium, strontium-90, and caesium-137. Brightness levels up to 1000 microlamberts are obtained, and a wide choice of colours can be produced. Beta-emitters are preferred because there is much less radiation damage to the phosphor than by alpha-emitters.

Voltage production is another application of radiation effects. This extremely small but direct conversion of radioactivity to electricity is attracting much attention. Several types of radioisotope batteries have been developed, operating on different principles. The direct-charging type builds up a potential as negative beta particles from a radioisotope leave one electrode and collect on another. The second and third types depend on induction of a current by the contact potential difference between dissimilar materials, in one case when ions are produced in a gas by the radiation, and in the other when a semi-conductor junction in silicon is energized by the radiation. In still another, the heat from radioactive decay is converted to electricity by thermocouples; in another, the light from a radioisotope-activated phosphor is converted by a photovoltaic cell. Such batteries produce minute amounts of current but are very useful, for example, in electronic circuits where long-lived, stable sources of potential are required.

Polymerization of monomers to form plastics is a radiation effect resulting from the breaking of molecular bonds. Many open bonds are formed in the path of each ionizing particle and result in active recombination into new forms and structures. A polymer produced by radiation can be quite different from a product polymerized chemically from the same material. Since no chemical is introduced as a catalyst, the product is relatively free from impurities which can alter its properties. Not only industrial products, such as plastics and synthetic rubbers, but also blood-plasma extenders can be polymerized to advantage by radiation.

A further effect of radiation on polymers is the initiation of cross-linking between neighbouring molecules. Side-chain bonds are rather easily broken by radiation and immediately join with similarly opened bonds in adjacent molecules. A quite rigid, three-dimensional structure is formed, having different strength, heat resistance, and other properties than the original. While radiation from radioisotopes may not compete with present commercial methods of producing many polymers, its ability to polymerize and cross-link yields some special materials not possible or practical by other means.

Sterilization of foods and drugs is another application of radiation effects. Although at present largely in the research stage, it will undoubtedly call for great quantities of radioisotopes in the future. Radiation in large enough doses can destroy harmful bacteria and enzymes in a material, without significantly raising its temperature. Although the necessary radiation doses cause unwanted changes in taste and colour in certain foods, others are quite unchanged and offer great commercial possibilities. Among the potential applications may be mentioned preservation of meat, poultry, and fish, killing of trichina in pork and of insects in grain, inhibiting of sprouting and spoilage in vegetables, extending the shelf life of canned meats and vegetables, and pasteurization of dairy products. While a good estimate of sterilization costs cannot as yet be made, it would seem that these will be in the neighbourhood of from 1 to 7 cents (0·9 to 6d) per pound. Future costs will depend in large measure on the feasibility and economics of obtaining large usable quantities of fission-product isotopes from spent reactor fuels.

The sterilization of drugs and other medical supplies seems to present fewer problems than the sterilization of food. Side-effects are not as important and radiation processing can assure "guaranteed" sterilization while avoiding the disadvantages of high-pressure steam sterilization. Judging from the effectiveness of experimental facilities, operating costs would compare favourably with present costs.

The ability of radiation to supply information by reflection from or transmission through material has proved a boon to industry. Most of the routine industrial applications are based on this principle of material affecting radiation. Radiography, for example, took a great stride forward when strong sources of gamma-ray-emitting isotopes such as cobalt-60 and iridium-192 became available. Radiographic testing of numerous materials and products became more convenient and economical. Many small foundries now maintain a routine radiographic inspection of their castings. Inspection teams can move along a new pipeline in the field, radiographing weld after weld in rapid succession.

Radioisotopes are supplying another long-felt need in industry with their ability to give rapid information as to thickness and density of material. The beta-gauge is the most commonly known radioactive device for this purpose. Beta-gauges are now completely established as a routine thickness-monitoring instrument, especially in sheet-processing industries with products such as steel, aluminium, and other metals, plastics, paper, cloth, and floor coverings. The rate of installation of these gauges is increasing rapidly.

Thickness gauges are not limited to the use of beta-emitters, appropriate gamma and X-ray emitters being employed in gauging larger thicknesses of sheet materials. For example, a gamma-ray density gauge has been developed to record continuously the density, and thus the weight, of sugar during a refinery process. A product or process material can be in containers or flowing in closed conduits, and still the gamma-ray density gauge can "see" it through the walls.

The great variety of materials which industry needs to measure is matched by the variety of radiations among the available radioisotopes. Near one extreme is the use of 67-kev beta radiation from nickel-63 to measure ink-film thicknesses on a lithographic press and, near the other, is the use of 1·3-mev gamma rays from cobalt-60 to gauge sheet steel.

Reflection-type gauges have been developed which take advantage of the backward scattering of radiation. They require only one side of a material to be accessible, radioisotope source and detector being mounted side by side. Using gamma sources, such instruments allow routine monitoring of internal corrosion in process tanks, logging the types of strata in an oil-well bore, and measurement of soil density. Beta-ray reflection gauges permit the measuring of thin films on base material of different atomic weight, such as gold plated on copper or plastic over steel. Wear-tests on traffic-marking paint, for example, have been made with such a gauge, which measures the paint film to within one ten-thousandth of an inch.

A great advantage of radioisotope gauges, in addition to their convenience and accuracy, lies in their ability to measure a material without contact. Swiftly moving strips of delicate and perhaps still moist or sticky product can be measured, where formerly production machinery had to be stopped while the strip was measured. In the manufacture of coated abrasives, for example, one company has long been using a series of five beta-gauges in one production process. These measure the thickness and amount of backing stock, adhesive layers, and abrasives as they are applied to the product passing swiftly through various stages. The resulting product is superior in uniformity and much saving in raw material is realized.

The use of these gauges leads naturally to automatic control of the processing equipment. Such automatic control is now fairly well established in processing adhesive tape, steel strip, cigarettes, rubber sheet, and paper, and in plastic calendering. Such diversity of application is a good illustration of their widespread usefulness.

The third category, radioactive tracer techniques, does not employ as many total curies of activity as will the production of radiation effects, and is not as numerous as the penetration and reflection techniques. It nevertheless includes many of the most interesting applications. Moreover, it can match the others in usefulness and economic value.

Many tracer techniques in industry have reached the routine operational state, usually where an object or material is to be followed or located or to be identified among others of its kind. For example, radioactive material is injected between successive shipments of petroleum products through a cross-country pipe-line and identifies the change-over by activating a continuous counter at a later switching terminal. Losses due to uncertainty as to region of mixing have been sharply reduced.

The petroleum industry is an outstanding example in its solving of technological problems with tracer isotopes. Fluid flow is of prime importance from the initial drilling of a well to final delivery of refinery products. Pumping a suspension of radioactive particles into a well and then logging the radioactivity along its length reveals leaks, open formations, and permeable zones. The latter zones are of interest as oil-bearing or oil-thieving areas or as pathways for conduction of water in an oilfield for secondary recovery.

Radioactive tracers are added to cement, used to block off unwanted zones, to evaluate its position and extent, and are added to pressurizing water to determine its entry into other wells. They are also added to the acid used to treat oil-bearing limestone strata for greater productivity, to tell by means of a counter lowered into the well when the acid is being forced into the proper zone.

The moving-marker technique for cross-country pipeline shipments is applied also in tracing movement of batches of oil through complex piping patterns in the refinery. Also, the rate of flow of solid catalyst particles in petroleum-cracking plants is monitored by timing the passage of an occasional radioactive bead.

Underground gas-storage fields utilize a porous formation, many hundreds of feet down, sealed above and below by impervious strata and reached by drilled wells. When a leak occurred recently, short-lived radioactive argon-41, emitting 1·3 mev gamma rays, was introduced through a well into the reservoir. Gas leakage, especially around loose-fitting well casings, could then be easily traced with detectors lowered through the casings. This is but one example of the power of radioiosotopes to detect leaks of all kinds which are a constant source of trouble in industry. A tracer amount of radioisotope can be introduced into a gas or liquid system and then either detected as it emerges from a leak, or followed, despite intervening structure, by means of its gamma radiation.

One of the most widely applicable and rewarding uses of tracer radioisotopes is in wear and corrosion studies. Radioactivity introduced into a machine part, cutting tool, or furnace lining is also present in the particles later worn or corroded from the surface. Thus, the amount or rate of removal is quickly and accurately measured by the activity appearing in the lubricating oil or furnace product. In another type of wear test a material applied to a surface is made radioactive. After wear, the amount of radiation shows how much material remains, and thus its resistance to wear. Many protective coatings are evaluated in this way.

A new development is the improvement of gamma-scattering gauges for the purpose of detecting corrosion in pipes from the outside. The improvement consists

of counting only the scattered and therefore much less energetic gamma rays, which are sorted from the original gammas by using a one-channel kick-sorter. Consequently, it is not necessary to shield the source and, by having source and counter as a very small unit near the pipe to be probed, a much better definition can be achieved. This development promises to be of the greatest significance in measuring corrosion of pipes, as the periodical shut-down of a plant for such an inspection is now unnecessary. It is too early to assess the commercial value of this application but an increase of several per cent of the total production of such a plant seems a probability.

Important progress has been made during the last year by developing a method with which it is possible to distinguish between different layers or liquids like oil and brine through steel and concrete, a tricky problem which presents itself in bore-holes. This has been solved by measuring the prompt gammas emitted on absorption of slow neutrons. The energies of the prompt gamma rays are characteristic of the neutron-absorbing nucleus. A polonium-beryllium neutron source and a gamma scintillation counter, in connection with a one-channel kick-sorter, were used. Field experiments have shown already that a clear distinction can be obtained between oil and brine through a steel pipe with a wall thickness of 1 cm which is set in concrete, even when the bore-hole is filled with oil. With this method it will be possible to detect a rise of the brine level which often puts a bore-hole out of commission. By using this simple device bore-holes will be saved from being fouled and the financial reward by employing these instruments may well prove larger than the construction of several atomic reactors.

As another example of the use of radioisotopes, after last year's Comet crash, one avenue to be explored was to find out if the disaster might have come about by the spillage of fuel. Kerosene which is used as fuel was labelled in one case with palladium-109-acetyl-acetonate and in another with palladium-109-diethyl-dithiocarbamate. Flight experiments were conducted in order to find if spillage occurred and, if so, whether the kerosene came near parts of the aircraft where an explosion could occur. These experiments were extremely successful in excluding this possibility from the list of possible reasons for the tragedy.

A special investigation of general interest is the marking of Thames mud in order to follow its movements. Experiments made in conjunction with the Hydraulic Research Station and the Port of London Authority were started last summer and are still continuing. The method used is to grind scandium glass to the right particle size, after which it is irradiated and mixed with a small amount of mud which has been scooped up from the bottom of the Thames. It is then released on the bottom of the Thames and the movement followed up by underwater Geiger counters. At last year's experiments the radioactive mud could be followed for two weeks without difficulty and it is hoped to solve some of the siltation problems of the Thames Estuary with this method. As siltation problems in general are very difficult to solve, this method may prove to be useful for any harbour. The reorganization of the dredging procedure may depend on the outcome of these experiments.

Benefits are derived by almost any industry adapting radiotracers to the solution of its problems. As an example in the pharmaceutical industry, rapid analysis for the vitamin B-12 content of large heterogeneous mixtures is performed by adding a small radioactive-labelled sample of the vitamin and using the isotope-dilution method. As an example from a widely different technology, the organic chemicals used in water flotation of mineral ores to cause a desired mineral to separate out are evaluated by tracer techniques. With labelled chemicals the conditions for and extent of adsorption of any particular mineral can be determined.

As tracers of molecules, rather than of material in bulk, radioisotopes are widely used in the study and control of chemical processes. Citing the petroleum industry again as an example, a great amount of research is being done on hydrocarbon chemistry. Carbon-14, deuterium, and tritium come naturally as tracers into this work. They have been of inestimable value in elucidating the mechanisms involved in alkylation, polymerization, catalytic cracking, and many other important reactions.

### Present and Potential Value of Uses of Radio-isotopes

The total economic value of isotope utilization is very great, but is difficult to assess exactly. It can, however, be measured by success in (1) saving time of personnel in basic and technological research, (2) increased speed in acquisition of knowledge, (3) saving materials and labour in manufacturing, (4) improving performance and durability of manufactured products, (5) increasing agricultural productivity, (6) decreasing losses from food spoilage, and (7) improving the health of the public. Although it is not possible to assign quantitative or monetary values to all these benefits, certain examples and generalizations will help to give an overall appraisal.

Even more important than the saving of time of scientific and technical personnel is the earlier application of results. A good example is the great saving in time of personnel in studies of all kinds of wear and corrosion. Older methods of observation were limited to pronounced changes and were slow. With tracer techniques, however, very small amounts of wear or corrosion can be measured quickly and accurately, so much so that the rate of obtaining results is speeded up by a factor of no less than 10, or even more.

Radioisotope techniques have already been applied to a host of wear studies such as wear of automotive and diesel-engine parts, electrical contacts, cutting tools, furnace linings, and rubber tyres. These techniques have also been applied to the determination of anti-wear qualities in various lubricating oils and the influence of different additives on these qualities. Corrosion studies using isotopes include testing the resistance of materials to corrosive agents and the effectiveness of various protective coatings such as metal plating, plastics, and paints.

Increased speed in gaining new knowledge, as mentioned above, depends not only on saving the time of research personnel but also in using new powerful research tools like radioisotope tracers, which can obtain results more directly than older methods. Much of the vast amount of work accomplished with radioisotopes in all fields has built up a body of knowledge, much of which would not have been found by other means. This new knowledge immediately helps to gain further knowledge and also is soon reflected in practical uses.

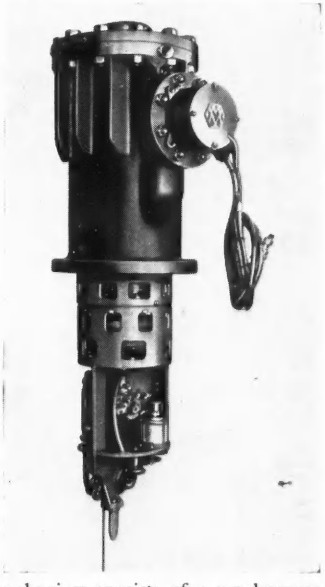
Radioisotopes constitute the most immediately realizable peaceful benefits for a nation undertaking a programme of atomic-energy development. Their use is also doubly rewarding. In addition to having many direct benefits, radioisotope utilization can have another very important result, the development of a large resource of professional and technical persons familiar with radiations and radioactivity. Since radiation and radioactivity are important occupational factors of the atomic-energy industry, an increasing number of personnel trained with radioisotopes both precedes and permits an expanding atomic programme.

The fostering of radioisotope uses in all fields will establish "seeds," from which interest and programmes in atomic energy will grow. This will also create uses for the increasingly abundant amounts of radiation and radioisotopes which many nations undoubtedly will soon have as byproducts of their research and power reactors.

# British Industrial Developments

## Thermal Reactor Equipment

An actuating mechanism for combined control and shut-off rods of a thermal reactor, designed to provide a slow " out " and two faster " in " speeds, and to hold the rod in any required position, is announced by Metropolitan Vickers Electrical Co., Ltd., of Trafford Park, Manchester. It is also capable of giving a controlled shut-off of the reactor independently of the electrical supply.



The mechanism consists of a synchronous control torque motor, fed from a variable-frequency supply, driving through a 20 : 1 reduction gear onto a cable reel. The speed of the rods to the shut-off condition is controlled by a permanent-magnet eddy-current brake. Rod-position indication is given by a geared magslip transmitter. The entire mechanism is dry-lubricated by molybdenum disulphide. 120 of these mechanisms are being supplied for the Calder " A " power station of the United Kingdom Atomic Energy Authority.

## Infra-Red Relays

Recent investigations by The British Thomson-Houston Co., Ltd., of Rugby, have led to the introduction of a new patented design of electronic relay using a lead sulphide photo-conductive cell as the sensitive element. The equipment is operated by the infra-red radiation from a hot body (even at black heat) and the built-in relay is capable of controlling an external electric circuit carrying up to 1 A at 440 V a.c. Unlike photo-electric relay equipment, no separate light source is necessary.

As the equipment was originally developed for use in a steelworks, it was essential that it should be of extremely robust construction, and the two types now available are suitable for service under the most arduous conditions. One of these, known as Model IR2, is capable of detecting a body four feet away at 400° C, while a more sensitive model, the IR3, will detect a hot

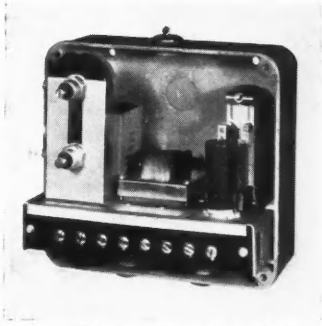


Fig. 1.

plate at 80° C (e.g., a kettle of hot water) under ideal conditions at the same distance. Features of particular interest are the high speed of response and high sensitivity.

The IR2 equipment illustrated consists of two units, the electronic circuit components and the P.O. relay (shown with its cover removed in Fig. 1), housed in a small die-cast box, and the detecting head (Fig. 2) incorporating the sensitive cell. It is essential to keep the cell reasonably cool for efficient operation and, to maintain it at a sufficiently low temperature (about 60° C), it is fitted in a specially designed water-cooled housing. By this means, adequate cooling is achieved, even when there is no alternative but to mount the detecting head in close proximity to very hot bodies, such as white-hot billets of steel.

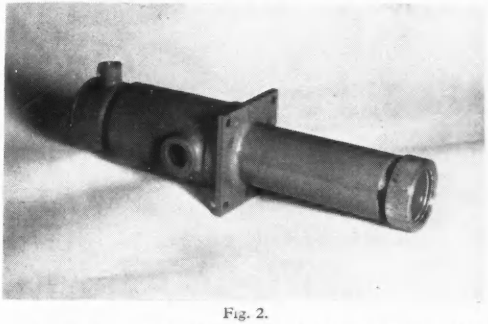


Fig. 2.

As with the Model IR2, the IR3 equipment is also made up of two units, although the electronic equipment is housed in two die-cast boxes of similar design mounted as one. The water-cooled head also differs in that a motor-driven disc is incorporated to interrupt the radiation falling on the cell, thus feeding an a.c. signal to the electronic amplifier.

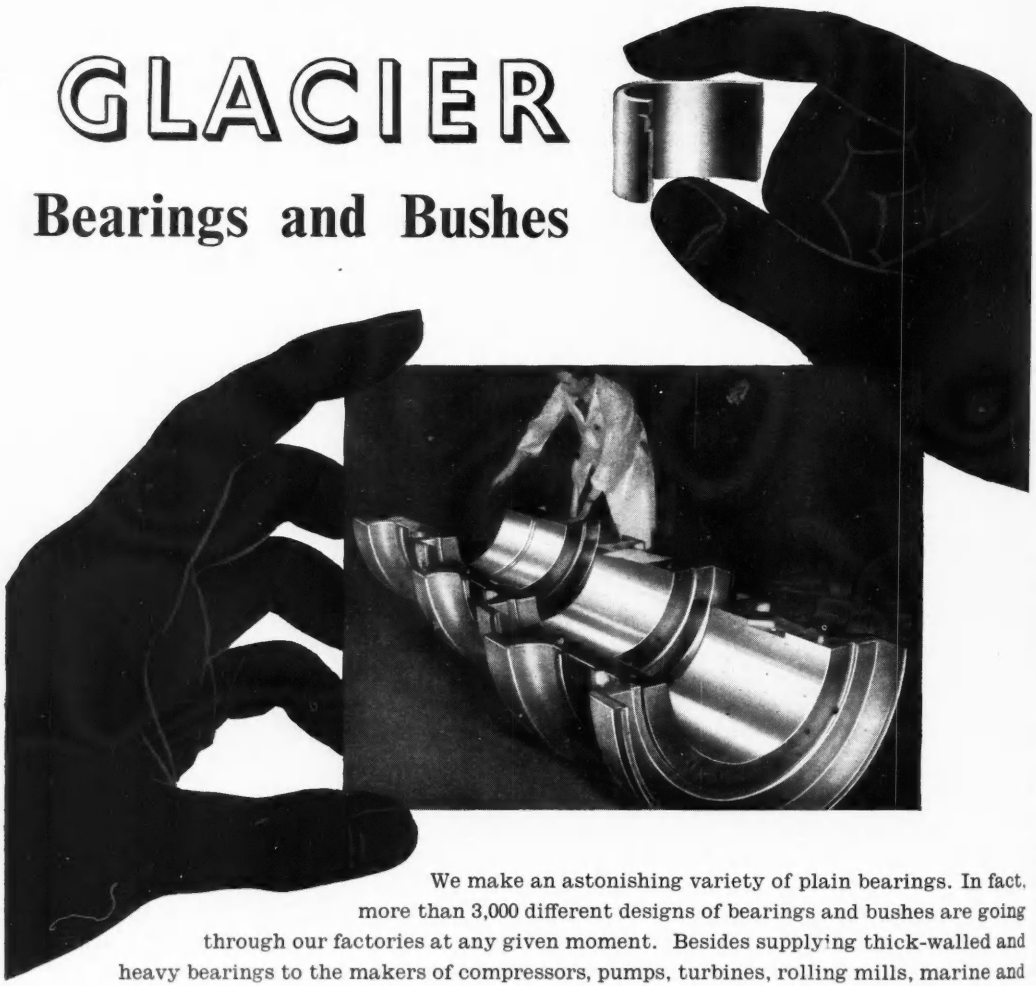
## Jig Borers

Since 1952, when the first of the model 2436 jig borers manufactured by the Newall Engineering Co. Ltd., of Peterborough, was produced, the Company has kept abreast of requirements by a series of modifications to the original design. Chief of these were changes to the quill and spindle assembly, to give greater spindle rigidity and running accuracy, higher spindle speeds, and an increased range of feeds.

Appreciating the coming change in production methods necessary for increased and more economical

# GLACIER

## Bearings and Bushes



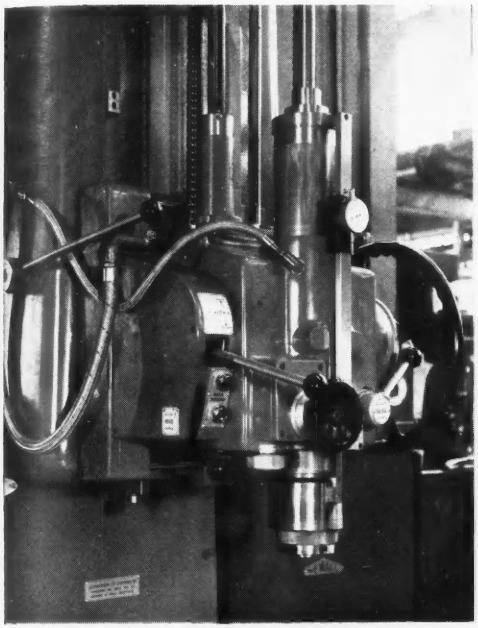
We make an astonishing variety of plain bearings. In fact, more than 3,000 different designs of bearings and bushes are going through our factories at any given moment. Besides supplying thick-walled and heavy bearings to the makers of compressors, pumps, turbines, rolling mills, marine and stationary diesels, we make thin-walled bearings for the motor industry and other engine builders. In short, we make all types of bearings for all industries.

THE GLACIER CORPORATION includes 3 production factories, 3 service stations; over 347,000 square feet of floor area, employing nearly 3,000 people, producing bearings and bushes in sizes from ⅛" to 4 ft. diameter, in value from 2d. to £200 each, serving thousands of customers in engineering and many other industries all over the world.

# GLACIER

stands for all plain bearings

THE GLACIER METAL COMPANY LIMITED, ALPERTON, WEMBLEY, MIDDLESEX, ENGLAND



output, combined with the highest possible accuracy, the feed-box (illustrated above) has now been entirely re-designed to include the following features :—

(a) The main-body diameter of the quill has been increased to 4½ in., permitting the use of a sturdier spindle.
(b) A built-in depth-measuring attachment of improved design has been incorporated.
(c) The entire quill travel of 9 in. requires less than one revolution of the larger coarse-feed dial and permits the use of a fixed " knock-out " position.
(d) A modified and more efficient quill clamp, for use during light milling operations, is fitted.
(e) An easy-to-read, large-diameter fine-feed dial gives 0·10 in. of feed per revolution.
(f) A new feed selector gives spindle feeds of 0·002, 0·004, 0·006, or 0·008 in., up and down.
(g) Single-lever differential clamping of the feed-box on the column ways, interlocked with push-button controls for the elevating motor, is incorporated.
(h) The main control lever gives fine and coarse hand feed, and also up-and-down power feed.

## Seamless Flexible Metal Hose

It is announced that a new Anglo-American company, Power Auxiliaries Limited, has been formed for the production of seamless flexible metal hose for use in aircraft and fighting vehicles. The new product, to be known as " Plessiflex " (Fig. 1), meets the long-felt demand for a flexible hosing with the ability to withstand, over long periods, the high temperatures and pressures associated with modern high-powered gas-turbine engines. The outstanding feature of this new technique is the prolonged life of the hose couplings, considerably in excess of methods at present in use. Power Auxiliaries Limited is a joint company formed by The Plessey Company Limited, of Ilford, Essex, and the DK Manufacturing Company, of Chicago, U.S.A. The hose is produced to material specifications of the American company, and to proving specifications of The Plessey Company for the whole assembly.

In appearance, " Plessiflex " is a continuous circular metal coil formed in seamless metal tubing (Fig. 2). Metals generally employed are stainless steel, brass, and bronze. Experiments will shortly commence with titanium, which has an extremely high melting point and outstanding resistance to metal fatigue.

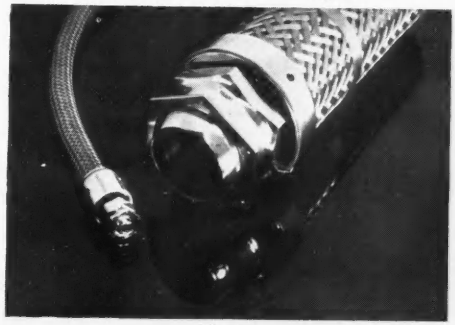


Fig. 1.

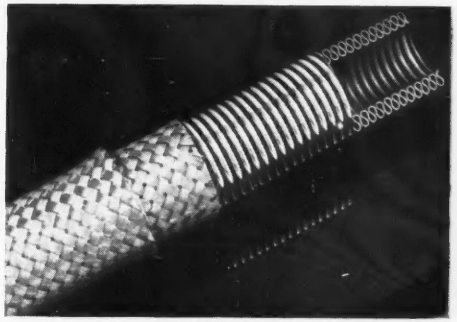


Fig. 2.

The hose assemblies have been subjected to rigorous tests by one of the leading aero-engine manufacturers in Great Britain and, as a result, a limited size range has been approved for production release. Tests continue on the remaining sizes, and it is hoped that a complete range of " Plessiflex " for aero-engine installations will shortly be available. Other potential applications of the new hose include service on engine steam lines, both static and marine, and numerous uses in the gas and chemical industries. Experiments in its use are also being conducted in the field of guided missiles.

## Heavy-Duty Contactors

By the addition of a new series of heavy-duty contactors, in capacities up to 750 A a.c. and to 1000 A d.c., The Electric Construction Company Limited, of Wolverhampton, have extended their range of automatic control gear. These contactors have completed mechanical type tests (five million operations), also electrical type tests (make-and-break at eight times full-load current, 100 operations at three-second intervals). Features of the new range include unit assembly ; interchangeability of all parts ; self-aligning, single-bolt fixing ; solid copper or silver-faced contacts ; powerful magnetic blow-outs for a.c. or d.c. service ; quick-acting release for inspection and service ; a fully floating self-aligning magnet, with leaf-spring damping ; and a voltage coil for a wide range of voltage without change of coil, with a quick-release magnet spring. Ancillary fittings include an isolator with interlock parts, HRC fuse mountings, overload magnets, etc.

These contactors can be provided with push-button stations or other master-control devices. The range includes a diaphragm type of timing device, so that

whether it is in large or small particles, whether it is indeed gaseous, whether it would rise high into the air or seep slowly along and into the ground, nevertheless, some notion of the possible spread of the hazard could be obtained by study of the meteorology and hydrology at the reactor site. It is desirable, for example, that the prevailing wind blow from the reactor to uninhabited areas. It is also desirable for the reactor site to be located away from a main watershed. From the point of view of the hazard alone, it is, of course, desirable to have the reactor site far from populous or vital industrial areas. It will not always be possible to obtain this remote location and still obtain economic utility from the reactor. For this reason, the importance of safe reactor designs, the development of contained fuses to minimize the possibility of a runaway accident, and the use of gas-tight containing vessels and buildings, are emphasized.

In the event of a reactor accident, assuming that good luck prevails and no one is killed, it may nevertheless be necessary to evacuate a large city, to abandon a major watershed, and very probably it would be necessary to make the reactor site itself a forbidden area for some years to come.

Nevertheless, it should be understood that accidents must necessarily be infrequent and, provided that they do not involve the release of more than a few tenths of a megawatt equivalent of fission products, remote siting of reactors should be unnecessary. It is considered that this degree of containment can be maintained by adherence to sound principles in the design, construction, and operation of nuclear plant. It is therefore concluded that the satisfactory siting of high-power reactors with suitable engineering safeguards will not present an insuperable problem in the development of nuclear power.

## RADIOISOTOPES

Radioisotopes are exceedingly abundant and widely useful byproducts of nuclear reactors. Reactor radioisotopes have now been distributed extensively for nine years and their use has grown rapidly. Nevertheless, they are still far from attaining their vast worldwide potential for gaining new knowledge and improving health and welfare.

As has been true for other nuclear developments, the concepts, discoveries, and instrumentation which have led to the production and use of radioisotopes have been international. It is interesting to note that uranium has had both a singular and rejuvenated role as a source of radioactivity. Uranium first brought to man's attention in 1896 the phenomenon of radioactivity, in itself a form of nuclear energy (although not then recognized as such); now, almost 60 years later, it provides by means of the uranium chain reaction a tremendous source of both useful energy and a broad array of new radioactive species. Uranium, source of many useful natural radioisotopes, has thus also become through the reactor the major source of the more numerous and more widely applicable man-made radioisotopes.

### The Power of Isotopes as Tracers

The sensitivity of the isotope tracer technique depends on detection of the isotopic label after dilution with other atoms of the same element. Dilution with atoms of dissimilar elements can usually be eliminated, if necessary, by chemical separations.

If a stable isotope with a natural abundance of about 1%, such as $C^{13}$, were concentrated to 100% abundance, it could be diluted only about $10^4$ times with normal carbon and still be detected. This is, of course, suitable for some experiments, but is a serious limitation for many. A stable isotope with a higher natural abundance would have a smaller limit of possible dilution. Deuterium, with a natural abundance of only 0·015% and obtainable almost isotopically pure, presents a most favourable stable isotope tracer. In this case, using a mass spectrometer, a dilution with normal hydrogen by almost $10^6$ times is detectable, although with difficulty.

The dilution attainable with a radioactive tracer depends on available activity per gram of the element, efficiency of the detector, and reliability of detection above the natural radiation background. For example, "carrier-free" or 100% $P^{32}$ has an activity of about $2{\cdot}9 \times 10^5$ curies/gm or $6{\cdot}4 \times 10^{17}$ disintegrations/min/gm. With ordinary Geiger-counter methods it is easy to detect less than 20 counts/min above background or around $10^{-16}$ grams of $P^{32}$. If the sample is diluted with stable phosphorus, self-absorption will reduce the amount detectable. However, self-absorption is greatly reduced and counting efficiency increased by new methods, where the radio material is placed inside a liquid scintillation medium or gas counter. Using the latest low-level counting techniques, in which the natural radiation background is minimized by shielding and anti-coincidence methods, it is possible to measure radioisotope samples containing only a few disintegrations/min/gm. For carrier-free $P^{32}$ this would in theory permit a dilution with ordinary phosphorus of about $10^{17}$. Even if this dilution is "theoretical," it is obvious that $P^{32}$ can be readily detected after tremendous dilution. Many other useful isotopes, such as $I^{131}$, have very high carrier-free activity and can be detected with comparable sensitivity.

In case the element has a radioactive isotope in nature, as for example tritium ($H^3$) and $C^{14}$, this activity becomes an inescapable part of the natural background for this element. For "living" (biosphere) carbon the activity is about 13 disintegrations/min/gm, whereas for carrier-free $C^{14}$ the activity is about $10^{13}$ d/min/gm. Theoretically, therefore, $C^{14}$ could be traced after dilution in "living" carbon almost a million million times. Tritium has an activity of about $2 \times 10^{16}$ d/min/gm, and its natural specific activity is extremely minute; consequently, it can be traced through an even greater dilution than $C^{14}$. Such sensitivities of detection are millions of times greater than for any other means.

In addition, the isotopic labelling technique can be unquestionably specific. An isotope of an element is chemically identical with the element, except for a small "isotope effect" in chemical reactions affected by differences in isotope mass. The isotope effect is demonstrated by altered reaction rates, but not by a qualitative difference in mechanism of reaction. Difference in reaction rates is considerable only for isotopes of great mass difference, such as those of hydrogen, but is demonstrable for isotopes of carbon. The effect can be taken into account, however, when it effects quantitative experiments.

Several criteria must be met for an isotope to serve as a "perfect" tracer. The dose of radiation or amount of chemical added must not affect the reaction studied. Also, the isotopic label must be in the proper chemical state or affixed in the proper molecular location. These criteria, however, are in general readily satisfied.

Available counting techniques permit almost any tracer experiment to be accomplished with amounts of radioactivity very much less than those which might affect the system. To avoid adding chemically toxic amounts of the tracer, it is often necessary to have very high specific activity material. Radioisotopes made by transmutation or fission are obtainable almost carrier-free; hence, specific activity is generally no problem. Radioisotopes produced by neutron absorption may have to be irradiated in a high-flux reactor to meet this criterion. Reactors with fluxes in the range of $10^{13}$ to $10^{14}$ neutrons/cm$^2$/sec produce sufficiently high specific activity in even the most toxic elements.

Techniques of multiple labelling with isotopes provide additional means of achieving specificity in tracer experiments. Different portions of a molecule can be labelled simultaneously with two or more

... Double or even triple labelling of organic compounds is accomplished with such isotopes as $H^2$, $H^3$, $C^{13}$, $C^{14}$, $N^{15}$, $P^{32}$, and $S^{35}$. Such labelling permits simultaneous tracing of individual portions of a complex molecule, thereby checking molecular decomposition, as well as eliminating the question of exact reproducibility of experiments.

It is usually possible to identify positively a radioactive isotope by its radiation and/or half-life. With proportional or scintillation counters and pulse-height discrimination circuits, it is often possible to use several radiotracers simultaneously in an experiment and to count them separately without chemical separation. Furthermore, with such discrimination equipment, it is possible to carry out accurate neutron activation analysis. The material to be analysed is irradiated in a reactor, and the induced radioactivities are differentiated. This technique can identify parts per million or even million million of certain elements. The method has, however, limitations. A high flux of neutrons is required; the unknown element must be suitably activated; and too many radioisotopes with similar radiation characteristics must not be produced simultaneously.

Other special powerful analytical procedures are possible with radioisotopes. Mention should be made of various types of " isotopic-dilution " techniques. An isotope-labelled compound of known isotopic ratio may first be added to a system containing the unlabelled compound. Then, after thorough mixing, an isotopic analysis of the altered ratio for an unknown portion of the total gives the dilution of the isotope label and thereby a quantitative measurement of the total amount of the compound originally present. This technique is useful when the system is very large or the compound cannot be quantitatively extracted.

A similar isotope technique is used to determine the success of chemical purification. The desired pure compound is properly synthesized with a radioisotope label. This is then mixed homogeneously with the compound being purified, and the specific activity determined. If, after repeated purifications, the specific activity of the compound remains constant, maximum purification has been achieved with the procedure. Use of this technique, together with chromatographic, electrophoresis, and ion-exchange separations, reveals constituents below conventional criteria of chemical purity.

Autoradiography should also be noted as a sensitive and detailed detection method for radioisotopes. It uses a photographic emulsion to obtain a picture of the distribution of radioactivity, for example, detailed location of radiomaterial in tissues or cells, or in the grain structure of metals. With fine-grain nuclear emulsions, resolution can be achieved down to about 5 microns. A new high-resolution wet-process autoradiography uses a very thin layer of sensitized silver bromide capable of giving resolution down to one micron. Although this is far from the resolution obtainable with good microscopes, when combined with the tracer technique it provides information not obtainable in other ways.

Great versatility is possible in the labelling of materials with isotopes. Useful radioisotope tracers can be produced for most elements. Fortunately, for those elements having radioisotopes with half-lives too short for tracer work, such as nitrogen and oxygen, it is possible to use the concentrated stable isotopes ($N^{15}$ and $O^{18}$). In a few cases, such as fluorine and copper, however, stable isotope tracing is not feasible, and the radioisotope also has a limited half-life. Aluminium was in the latter category, but recently a long-lived isotope $Al^{26}$ has been produced by cyclotron bombardment of magnesium and, although obtainable only in low yield, may provide a tracer for this important element. The overall situation for tracing elements is thus most fortunate. Luckily also, most of the important radiotracers can be made with a reactor.

Furthermore, methods have been devised for synthesizing a large number of isotope-labelled compounds, either by chemical or biological means. Over 1000 labelled compounds are now readily available. These include biochemicals, pharmaceuticals, and industrial chemicals. Techniques have also been devised for labelling a wide variety of organisms such as blood cells, bacteria, viruses, and higher organisms. Fabricated materials, such as piston rings and machine tools, can be activated directly by irradiation in the reactor. The total result is a very large number of elements, compounds, materials, and organisms which have been made radioactive for tracer studies.

The radiotracer technique thus has the combined power of tremendous sensitivity, unquestioned specificity, and wide versatility. Such a great extension of power of observation supports the prediction that isotopes may become a scientific tool as commonly and as widely necessary as a microscope.

## Scope of Radiation Sources

In addition to their use as tracers, radioisotopes have another broad and important category of application as sources of radiation. For this use chemical identity is not the major interest, but rather the character and output of radiation. Here also radioisotopes are very versatile. They provide alpha, beta, gamma, and in some cases X-ray sources. Also, by secondary means they may provide X-ray and neutron sources. The range of available radiation energies and half-lives is broad enough to cover requirements for a large variety of practical uses.

Reactors provide radioisotopes in far greater intensities and at much lower cost than do natural sources or particle accelerators. The tremendous production capacity of the reactor, while very desirable to produce isotopes even for tracer uses, is absolutely essential for wide-scale application of radioisotopes as radiation sources. For example, the activity of gamma-ray-emitting isotopes now used in radiography totals thousands of curies, and for teletherapy of cancer the ultimate use will total hundreds of thousands of curies. Large-scale sterilization of foods and drugs would require millions of curies.

The only reactor-produced alpha-ray emitter now used widely in industry is $Po^{210}$. It is not only useful as an alpha source, as in self-luminous compounds and static eliminators, but is extensively used with beryllium for neutron sources. Reactor production far surpasses the normal supplies of natural polonium and at much less cost. Po-Be sources containing 50 curies or more per source are readily available. The yield of neutrons averages about $2{\cdot}3 \times 10^6$ n/sec/curie. Many Po-Be neutron sources are used for neutron " logging " of oil wells and other techniques which depend on neutron reflection from hydrogenous material. Other alpha-ray emitters, such as plutonium-239, can be produced by reactors. Some of these would have certain advantages over polonium, particularly in longer half-life, but their applications as sources await further development.

Many beta-ray emitters can be and are produced in reactors. Thus, for instance, $Sr^{90}$ is extracted from uranium-fission waste and $Tl^{204}$ is produced by reactor irradiation of thallium. These two beta emitters find wide industrial use at present, because of the combination of long life and energetic radiation. For some industrial applications, however, the low-energy beta rays of $H^3$ are useful. Because $H^3$ can be produced cheaply, is comparatively safe to handle, and has a desirable half-life, it should come into extensive industrial use.

In the same way, many important gamma-ray emitters can be produced in the reactor. For biological and medical purposes, including therapy, the short-lived

isotopes, such as $Na^{24}$, $I^{131}$, and $Au^{198}$ are extremely useful gamma-ray emitters. $Co^{60}$ and $Cs^{137}$ have many industrial uses, owing to their long life and high energy radiation, while $Tm^{170}$ is valuable for its very low-energy gamma-ray output, though its half-life of 127 days calls for frequent source replacement.

Most gamma-ray radioisotopes also emit beta rays. However, for most uses the beta rays are of no consequence or can be filtered out. $Fe^{55}$ is an isotope with no beta rays and gives soft manganese X-rays with special applications.

It should also be noted that beta rays can excite X-rays (bremsstrahlung) and that low-intensity X-ray sources can be obtained from high-intensity beta-ray sources. Lack of long-lived low-energy gamma-emitting isotopes has prompted the development of such beta-ray-excited X-ray sources. These sources can have a long life and a wide range of energy spectra; consequently, many industrial applications can be expected.

## Versatility of the Principles of Utilization

The tremendous variety of uses of radioisotopes stems from three very versatile basic principles applicable to radiations, i.e., (1) radiation affects materials, (2) materials affect radiation, and (3) radiation traces materials.

The first of these three principles, the use of radiation to affect materials, is the least exploited at present but is expected to play a large role in the future. Although radiation can have many different effects on materials, these effects all result from ionization or excitation of atoms or molecules. Thus, the radiation from radioisotopes is applied to produce ionization of air in static eliminators, excitation of phosphorescent light sources, destruction of bacteria in foods and drugs, activation of chemical reactions, polymerization of organic materials, alteration of material strength and conductivity, gene changes, and therapeutic results in patients.

In the second principle of use, radiation is directed at or through a material to gain information about the material. Here, the requirements are a radioactive source, the material, and a detector to record the radiation transmitted through or reflected from the material. All interactions of radiation with materials lower its energy or remove part of it from a beam. The thickness of a material, its density, atomic number, and atomic structure have different effects on different radiations. Therefore, much can be learned regarding these properties by observing their effects in absorbing or reflecting radiations.

The major applications of this principle are industrial and clinical radiography, thickness and density gauging, and analysis by radiation penetration. Other important uses include liquid-level gauging and applications where an object is revealed by its effect on a beam of radiation. The principle is also applied to industrial sorting and packaging problems.

In applications based on the third principle, the radioisotope is incorporated in or carried by the substance of interest. This substance can then be located or traced, or parts of it measured quantitatively. Radiomaterial can be traced in bulk, as in locating markers, determining fluid flow, following motion of material, detecting leaks, and measuring wear and abrasion. Also, radioisotopes as tracer atoms are used to study all kinds of chemical, physical-chemical, and biochemical problems. In technology, tracer uses include studies of corrosion, diffusion, detergency, catalysis, and the kinetics and mechanisms of reactions.

It is obvious that each of these principles has much versatility in application. They provide a wide spectrum of uses, covering many fields of technology, as well as varieties of industrial materials, processes, and products.

## Specific Illustrations of Usefulness

Luminescence, an effect of radiation on special phosphor materials, provides self-luminous material for safety marking in aircraft, mines, and public buildings, for low-level illumination, and for standard light sources. Isotopes used for the purpose include polonium, tritium, strontium-90, and caesium-137. Brightness levels up to 1000 microlamberts are obtained, and a wide choice of colours can be produced. Beta-emitters are preferred because there is much less radiation damage to the phosphor than by alpha-emitters.

Voltage production is another application of radiation effects. This extremely small but direct conversion of radioactivity to electricity is attracting much attention. Several types of radioisotope batteries have been developed, operating on different principles. The direct-charging type builds up a potential as negative beta particles from a radioisotope leave one electrode and collect on another. The second and third types depend on induction of a current by the contact potential difference between dissimilar materials, in one case when ions are produced in a gas by the radiation, and in the other when a semi-conductor junction in silicon is energized by the radiation. In still another, the heat from radioactive decay is converted to electricity by thermocouples; in another, the light from a radioisotope-activated phosphor is converted by a photovoltaic cell. Such batteries produce minute amounts of current but are very useful, for example, in electronic circuits where long-lived, stable sources of potential are required.

Polymerization of monomers to form plastics is a radiation effect resulting from the breaking of molecular bonds. Many open bonds are formed in the path of each ionizing particle and result in active recombination into new forms and structures. A polymer produced by radiation can be quite different from a product polymerized chemically from the same material. Since no chemical is introduced as a catalyst, the product is relatively free from impurities which can alter its properties. Not only industrial products, such as plastics and synthetic rubbers, but also blood-plasma extenders can be polymerized to advantage by radiation.

A further effect of radiation on polymers is the initiation of cross-linking between neighbouring molecules. Side-chain bonds are rather easily broken by radiation and immediately join with similarly opened bonds in adjacent molecules. A quite rigid, three-dimensional structure is formed, having different strength, heat resistance, and other properties than the original. While radiation from radioisotopes may not compete with present commercial methods of producing many polymers, its ability to polymerize and cross-link yields some special materials not possible or practical by other means.

Sterilization of foods and drugs is another application of radiation effects. Although at present largely in the research stage, it will undoubtedly call for great quantities of radioisotopes in the future. Radiation in large enough doses can destroy harmful bacteria and enzymes in a material, without significantly raising its temperature. Although the necessary radiation doses cause unwanted changes in taste and colour in certain foods, others are quite unchanged and offer great commercial possibilities. Among the potential applications may be mentioned preservation of meat, poultry, and fish, killing of trichina in pork and of insects in grain, inhibiting of sprouting and spoilage in vegetables, extending the shelf life of canned meats and vegetables, and pasteurization of dairy products. While a good estimate of sterilization costs cannot as yet be made, it would seem that these will be in the neighbourhood of from 1 to 7 cents (0·9 to 6d) per pound. Future costs will depend in large measure on the feasibility and economics of obtaining large usable quantities of fission-product isotopes from spent reactor fuels.

The sterilization of drugs and other medical supplies seems to present fewer problems than the sterilization of food. Side-effects are not as important and radiation processing can assure " guaranteed " sterilization while avoiding the disadvantages of high-pressure steam sterilization. Judging from the effectiveness of experimental facilities, operating costs would compare favourably with present costs.

The ability of radiation to supply information by reflection from or transmission through material has proved a boon to industry. Most of the routine industrial applications are based on this principle of material affecting radiation. Radiography, for example, took a great stride forward when strong sources of gamma-ray-emitting isotopes such as cobalt-60 and iridium-192 became available. Radiographic testing of numerous materials and products became more convenient and economical. Many small foundries now maintain a routine radiographic inspection of their castings. Inspection teams can move along a new pipeline in the field, radiographing weld after weld in rapid succession.

Radioisotopes are supplying another long-felt need in industry with their ability to give rapid information as to thickness and density of material. The beta-gauge is the most commonly known radioactive device for this purpose. Beta-gauges are now completely established as a routine thickness-monitoring instrument, especially in sheet-processing industries with products such as steel, aluminium, and other metals, plastics, paper, cloth, and floor coverings. The rate of installation of these gauges is increasing rapidly.

Thickness gauges are not limited to the use of beta-emitters, appropriate gamma and X-ray emitters being employed in gauging larger thicknesses of sheet materials. For example, a gamma-ray density gauge has been developed to record continuously the density, and thus the weight, of sugar during a refinery process. A product or process material can be in containers or flowing in closed conduits, and still the gamma-ray density gauge can " see " it through the walls.

The great variety of materials which industry needs to measure is matched by the variety of radiations among the available radioisotopes. Near one extreme is the use of 67-kev beta radiation from nickel-63 to measure ink-film thicknesses on a lithographic press and, near the other, is the use of 1·3-mev gamma rays from cobalt-60 to gauge sheet steel.

Reflection-type gauges have been developed which take advantage of the backward scattering of radiation. They require only one side of a material to be accessible, radioisotope source and detector being mounted side by side. Using gamma sources, such instruments allow routine monitoring of internal corrosion in process tanks, logging the types of strata in an oil-well bore, and measurement of soil density. Beta-ray reflection gauges permit the measuring of thin films on base material of different atomic weight, such as gold plated on copper or plastic over steel. Wear-tests on traffic-marking paint, for example, have been made with such a gauge, which measures the paint film to within one ten-thousandth of an inch.

A great advantage of radioisotope gauges, in addition to their convenience and accuracy, lies in their ability to measure a material without contact. Swiftly moving strips of delicate and perhaps still moist or sticky product can be measured, where formerly production machinery had to be stopped while the strip was measured. In the manufacture of coated abrasives, for example, one company has long been using a series of five beta-gauges in one production process. These measure the thickness and amount of backing stock, adhesive layers, and abrasives as they are applied to the product passing swiftly through various stages. The resulting product is superior in uniformity and much saving in raw material is realized.

The use of these gauges leads naturally to automatic control of the processing equipment. Such automatic control is now fairly well established in processing adhesive tape, steel strip, cigarettes, rubber sheet, and paper, and in plastic calendering. Such diversity of application is a good illustration of their widespread usefulness.

The third category, radioactive tracer techniques, does not employ as many total curies of activity as will the production of radiation effects, and is not as numerous as the penetration and reflection techniques. It nevertheless includes many of the most interesting applications. Moreover, it can match the others in usefulness and economic value.

Many tracer techniques in industry have reached the routine operational state, usually where an object or material is to be followed or located or to be identified among others of its kind. For example, radioactive material is injected between successive shipments of petroleum products through a cross-country pipe-line and identifies the change-over by activating a continuous counter at a later switching terminal. Losses due to uncertainty as to region of mixing have been sharply reduced.

The petroleum industry is an outstanding example in its solving of technological problems with tracer isotopes. Fluid flow is of prime importance from the initial drilling of a well to final delivery of refinery products. Pumping a suspension of radioactive particles into a well and then logging the radioactivity along its length reveals leaks, open formations, and permeable zones. The latter zones are of interest as oil-bearing or oil-thieving areas or as pathways for conduction of water in an oilfield for secondary recovery.

Radioactive tracers are added to cement, used to block off unwanted zones, to evaluate its position and extent, and are added to pressurizing water to determine its entry into other wells. They are also added to the acid used to treat oil-bearing limestone strata for greater productivity, to tell by means of a counter lowered into the well when the acid is being forced into the proper zone.

The moving-marker technique for cross-country pipeline shipments is applied also in tracing movement of batches of oil through complex piping patterns in the refinery. Also, the rate of flow of solid catalyst particles in petroleum-cracking plants is monitored by timing the passage of an occasional radioactive bead.

Underground gas-storage fields utilize a porous formation, many hundreds of feet down, sealed above and below by impervious strata and reached by drilled wells. When a leak occurred recently, short-lived radioactive argon-41, emitting 1·3 mev gamma rays, was introduced through a well into the reservoir. Gas leakage, especially around loose-fitting well casings, could then be easily traced with detectors lowered through the casings. This is but one example of the power of radioisotopes to detect leaks of all kinds which are a constant source of trouble in industry. A tracer amount of radioisotope can be introduced into a gas or liquid system and then either detected as it emerges from a leak, or followed, despite intervening structure, by means of its gamma radiation.

One of the most widely applicable and rewarding uses of tracer radioisotopes is in wear and corrosion studies. Radioactivity introduced into a machine part, cutting tool, or furnace lining is also present in the particles later worn or corroded from the surface. Thus, the amount or rate of removal is quickly and accurately measured by the activity appearing in the lubricating oil or furnace product. In another type of wear test a material applied to a surface is made radioactive. After wear, the amount of radiation shows how much material remains, and thus its resistance to wear. Many protective coatings are evaluated in this way.

A new development is the improvement of gamma-scattering gauges for the purpose of detecting corrosion in pipes from the outside. The improvement consists

of counting only the scattered and therefore much less energetic gamma rays, which are sorted from the original gammas by using a one-channel kick-sorter. Consequently, it is not necessary to shield the source and, by having source and counter as a very small unit near the pipe to be probed, a much better definition can be achieved. This development promises to be of the greatest significance in measuring corrosion of pipes, as the periodical shut-down of a plant for such an inspection is now unnecessary. It is too early to assess the commercial value of this application but an increase of several per cent of the total production of such a plant seems a probability.

Important progress has been made during the last year by developing a method with which it is possible to distinguish between different layers or liquids like oil and brine through steel and concrete, a tricky problem which presents itself in bore-holes. This has been solved by measuring the prompt gammas emitted on absorption of slow neutrons. The energies of the prompt gamma rays are characteristic of the neutron-absorbing nucleus. A polonium-beryllium neutron source and a gamma scintillation counter, in connection with a one-channel kick-sorter, were used. Field experiments have shown already that a clear distinction can be obtained between oil and brine through a steel pipe with a wall thickness of 1 cm which is set in concrete, even when the bore-hole is filled with oil. With this method it will be possible to detect a rise of the brine level which often puts a bore-hole out of commission. By using this simple device bore-holes will be saved from being fouled and the financial reward by employing these instruments may well prove larger than the construction of several atomic reactors.

As another example of the use of radioisotopes, after last year's Comet crash, one avenue to be explored was to find out if the disaster might have come about by the spillage of fuel. Kerosene which is used as fuel was labelled in one case with palladium-109-acetyl-acetonate and in another with palladium-109-diethyl-dithiocarbamate. Flight experiments were conducted in order to find if spillage occurred and, if so, whether the kerosene came near parts of the aircraft where an explosion could occur. These experiments were extremely successful in excluding this possibility from the list of possible reasons for the tragedy.

A special investigation of general interest is the marking of Thames mud in order to follow its movements. Experiments made in conjunction with the Hydraulic Research Station and the Port of London Authority were started last summer and are still continuing. The method used is to grind scandium glass to the right particle size, after which it is irradiated and mixed with a small amount of mud which has been scooped up from the bottom of the Thames. It is then released on the bottom of the Thames and the movement followed up by underwater Geiger counters. At last year's experiments the radioactive mud could be followed for two weeks without difficulty and it is hoped to solve some of the siltation problems of the Thames Estuary with this method. As siltation problems in general are very difficult to solve, this method may prove to be useful for any harbour. The reorganization of the dredging procedure may depend on the outcome of these experiments.

Benefits are derived by almost any industry adapting radiotracers to the solution of its problems. As an example in the pharmaceutical industry, rapid analysis for the vitamin B-12 content of large heterogeneous mixtures is performed by adding a small radioactive-labelled sample of the vitamin and using the isotope-dilution method. As an example from a widely different technology, the organic chemicals used in water flotation of mineral ores to cause a desired mineral to separate out are evaluated by tracer techniques. With labelled chemicals the conditions for and extent of adsorption of any particular mineral can be determined.

As tracers of molecules, rather than of material in bulk, radioisotopes are widely used in the study and control of chemical processes. Citing the petroleum industry again as an example, a great amount of research is being done on hydrocarbon chemistry. Carbon-14, deuterium, and tritium come naturally as tracers into this work. They have been of inestimable value in elucidating the mechanisms involved in alkylation, polymerization, catalytic cracking, and many other important reactions.

### Present and Potential Value of Uses of Radio-isotopes

The total economic value of isotope utilization is very great, but is difficult to assess exactly. It can, however, be measured by success in (1) saving time of personnel in basic and technological research, (2) increased speed in acquisition of knowledge, (3) saving materials and labour in manufacturing, (4) improving performance and durability of manufactured products, (5) increasing agricultural productivity, (6) decreasing losses from food spoilage, and (7) improving the health of the public. Although it is not possible to assign quantitative or monetary values to all these benefits, certain examples and generalizations will help to give an overall appraisal.

Even more important than the saving of time of scientific and technical personnel is the earlier application of results. A good example is the great saving in time of personnel in studies of all kinds of wear and corrosion. Older methods of observation were limited to pronounced changes and were slow. With tracer techniques, however, very small amounts of wear or corrosion can be measured quickly and accurately, so much so that the rate of obtaining results is speeded up by a factor of no less than 10, or even more.

Radioisotope techniques have already been applied to a host of wear studies such as wear of automotive and diesel-engine parts, electrical contacts, cutting tools, furnace linings, and rubber tyres. These techniques have also been applied to the determination of anti-wear qualities in various lubricating oils and the influence of different additives on these qualities. Corrosion studies using isotopes include testing the resistance of materials to corrosive agents and the effectiveness of various protective coatings such as metal plating, plastics, and paints.

Increased speed in gaining new knowledge, as mentioned above, depends not only on saving the time of research personnel but also in using new powerful research tools like radioisotope tracers, which can obtain results more directly than older methods. Much of the vast amount of work accomplished with radioisotopes in all fields has built up a body of knowledge, much of which would not have been found by other means. This new knowledge immediately helps to gain further knowledge and also is soon reflected in practical uses.

Radioisotopes constitute the most immediately realizable peaceful benefits for a nation undertaking a programme of atomic-energy development. Their use is also doubly rewarding. In addition to having many direct benefits, radioisotope utilization can have another very important result, the development of a large resource of professional and technical persons familiar with radiations and radioactivity. Since radiation and radioactivity are important occupational factors of the atomic-energy industry, an increasing number of personnel trained with radioisotopes both precedes and permits an expanding atomic programme.

The fostering of radioisotope uses in all fields will establish "seeds," from which interest and programmes in atomic energy will grow. This will also create uses for the increasingly abundant amounts of radiation and radioisotopes which many nations undoubtedly will soon have as byproducts of their research and power reactors.

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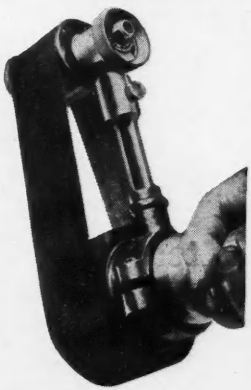

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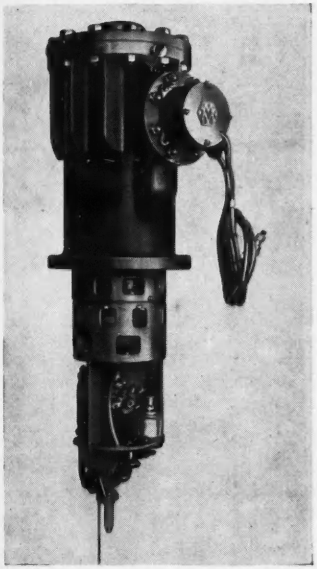
# British Industrial Developments

## Thermal Reactor Equipment

An actuating mechanism for combined control and shut-off rods of a thermal reactor, designed to provide a slow "out" and two faster "in" speeds, and to hold the rod in any required position, is announced by Metropolitan Vickers Electrical Co., Ltd., of Trafford Park, Manchester. It is also capable of giving a controlled shut-off of the reactor independently of the electrical supply.



The mechanism consists of a synchronous control torque motor, fed from a variable-frequency supply, driving through a 20 : 1 reduction gear onto a cable reel. The speed of the rods to the shut-off condition is controlled by a permanent-magnet eddy-current brake. Rod-position indication is given by a geared magslip transmitter. The entire mechanism is dry-lubricated by molybdenum disulphide. 120 of these mechanisms are being supplied for the Calder "A" power station of the United Kingdom Atomic Energy Authority.

## Infra-Red Relays

Recent investigations by The British Thomson-Houston Co., Ltd., of Rugby, have led to the introduction of a new patented design of electronic relay using a lead sulphide photo-conductive cell as the sensitive element. The equipment is operated by the infra-red radiation from a hot body (even at black heat) and the built-in relay is capable of controlling an external electric circuit carrying up to 1 A at 440 V a.c. Unlike photo-electric relay equipment, no separate light source is necessary.

As the equipment was originally developed for use in a steelworks, it was essential that it should be of extremely robust construction, and the two types now available are suitable for service under the most arduous conditions. One of these, known as Model IR2, is capable of detecting a body four feet away at 400° C, while a more sensitive model, the IR3, will detect a hot

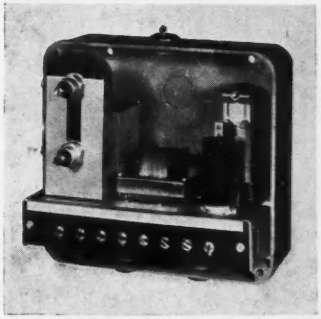


Fig. 1.

plate at 80° C (e.g., a kettle of hot water) under ideal conditions at the same distance. Features of particular interest are the high speed of response and high sensitivity.

The IR2 equipment illustrated consists of two units, the electronic circuit components and the P.O. relay (shown with its cover removed in Fig. 1), housed in a small die-cast box, and the detecting head (Fig. 2) incorporating the sensitive cell. It is essential to keep the cell reasonably cool for efficient operation and, to maintain it at a sufficiently low temperature (about 60° C), it is fitted in a specially designed water-cooled housing. By this means, adequate cooling is achieved, even when there is no alternative but to mount the detecting head in close proximity to very hot bodies, such as white-hot billets of steel.

Fig. 2.

As with the Model IR2, the IR3 equipment is also made up of two units, although the electronic equipment is housed in two die-cast boxes of similar design mounted as one. The water-cooled head also differs in that a motor-driven disc is incorporated to interrupt the radiation falling on the cell, thus feeding an a.c. signal to the electronic amplifier.

## Jig Borers

Since 1952, when the first of the model 2436 jig borers manufactured by the Newall Engineering Co. Ltd., of Peterborough, was produced, the Company has kept abreast of requirements by a series of modifications to the original design. Chief of these were changes to the quill and spindle assembly, to give greater spindle rigidity and running accuracy, higher spindle speeds, and an increased range of feeds.

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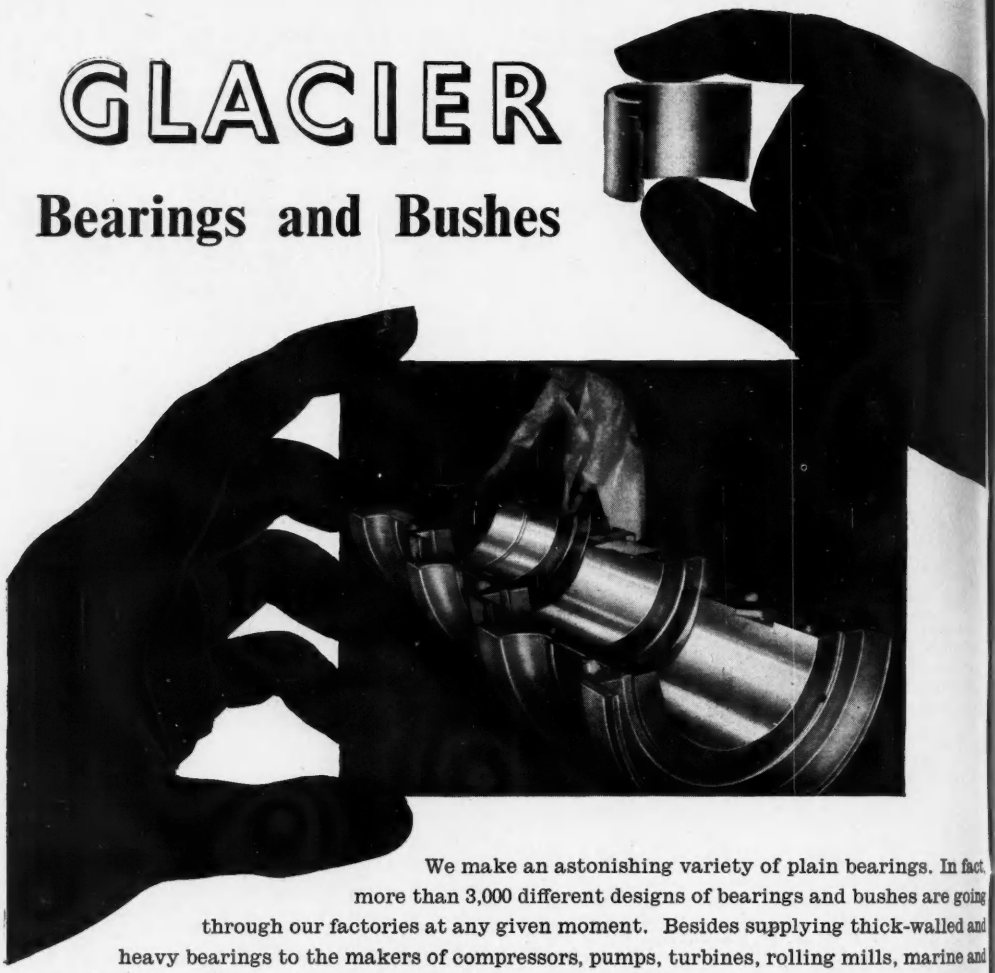

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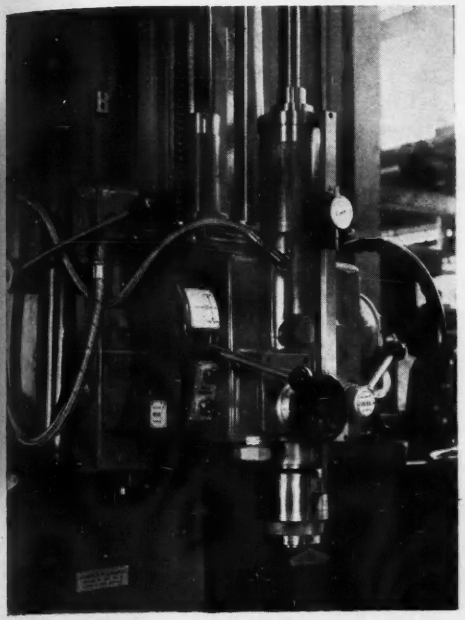

output, combined with the highest possible accuracy, the feed-box (illustrated above) has now been entirely re-designed to include the following features :—

(a) The main-body diameter of the quill has been increased to 4½ in., permitting the use of a sturdier spindle.
(b) A built-in depth-measuring attachment of improved design has been incorporated.
(c) The entire quill travel of 9 in. requires less than one revolution of the larger coarse-feed dial and permits the use of a fixed " knock-out " position.
(d) A modified and more efficient quill clamp, for use during light milling operations, is fitted.
(e) An easy-to-read, large-diameter fine-feed dial gives 0·10 in. of feed per revolution.
(f) A new feed selector gives spindle feeds of 0·002, 0·004, 0·006, or 0·008 in., up and down.
(g) Single-lever differential clamping of the feed-box on the column ways, interlocked with push-button controls for the elevating motor, is incorporated.
(h) The main control lever gives fine and coarse hand feed, and also up-and-down power feed.

## Seamless Flexible Metal Hose

It is announced that a new Anglo-American company, Power Auxiliaries Limited, has been formed for the production of seamless flexible metal hose for use in aircraft and fighting vehicles. The new product, to be known as " Plessiflex " (Fig. 1), meets the long-felt demand for a flexible hosing with the ability to withstand, over long periods, the high temperatures and pressures associated with modern high-powered gas-turbine engines. The outstanding feature of this new technique is the prolonged life of the hose couplings, considerably in excess of methods at present in use. Power Auxiliaries Limited is a joint company formed by The Plessey Company Limited, of Ilford, Essex, and the DK Manufacturing Company, of Chicago, U.S.A. The hose is produced to material specifications of the American company, and to proving specifications of The Plessey Company for the whole assembly.

In appearance, " Plessiflex " is a continuous circular metal coil formed in seamless metal tubing (Fig. 2). Metals generally employed are stainless steel, brass, and bronze. Experiments will shortly commence with titanium, which has an extremely high melting point and outstanding resistance to metal fatigue.

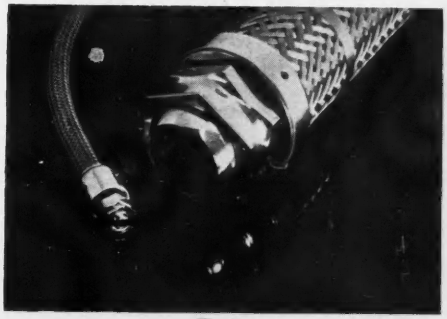

Fig. 1.

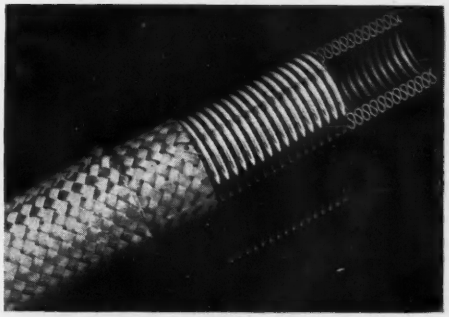

Fig. 2.

The hose assemblies have been subjected to rigorous tests by one of the leading aero-engine manufacturers in Great Britain and, as a result, a limited size range has been approved for production release. Tests continue on the remaining sizes, and it is hoped that a complete range of " Plessiflex " for aero-engine installations will shortly be available. Other potential applications of the new hose include service on engine steam lines, both static and marine, and numerous uses in the gas and chemical industries. Experiments in its use are also being conducted in the field of guided missiles.

## Heavy-Duty Contactors

By the addition of a new series of heavy-duty contactors, in capacities up to 750 A a.c. and to 1000 A d.c., The Electric Construction Company Limited, of Wolverhampton, have extended their range of automatic control gear. These contactors have completed mechanical type tests (five million operations), also electrical type tests (make-and-break at eight times full-load current, 100 operations at three-second intervals). Features of the new range include unit assembly; interchangeability of all parts; self-aligning, single-bolt fixing; solid copper or silver-faced contacts; powerful magnetic blow-outs for a.c. or d.c. service; quick-acting release for inspection and service; a fully floating self-aligning magnet, with leaf-spring damping; and a voltage coil for a wide range of voltage without change of coil, with a quick-release magnet spring. Ancillary fittings include an isolator with interlock parts, HRC fuse mountings, overload magnets, etc.

These contactors can be provided with push-button stations or other master-control devices. The range includes a diaphragm type of timing device, so that

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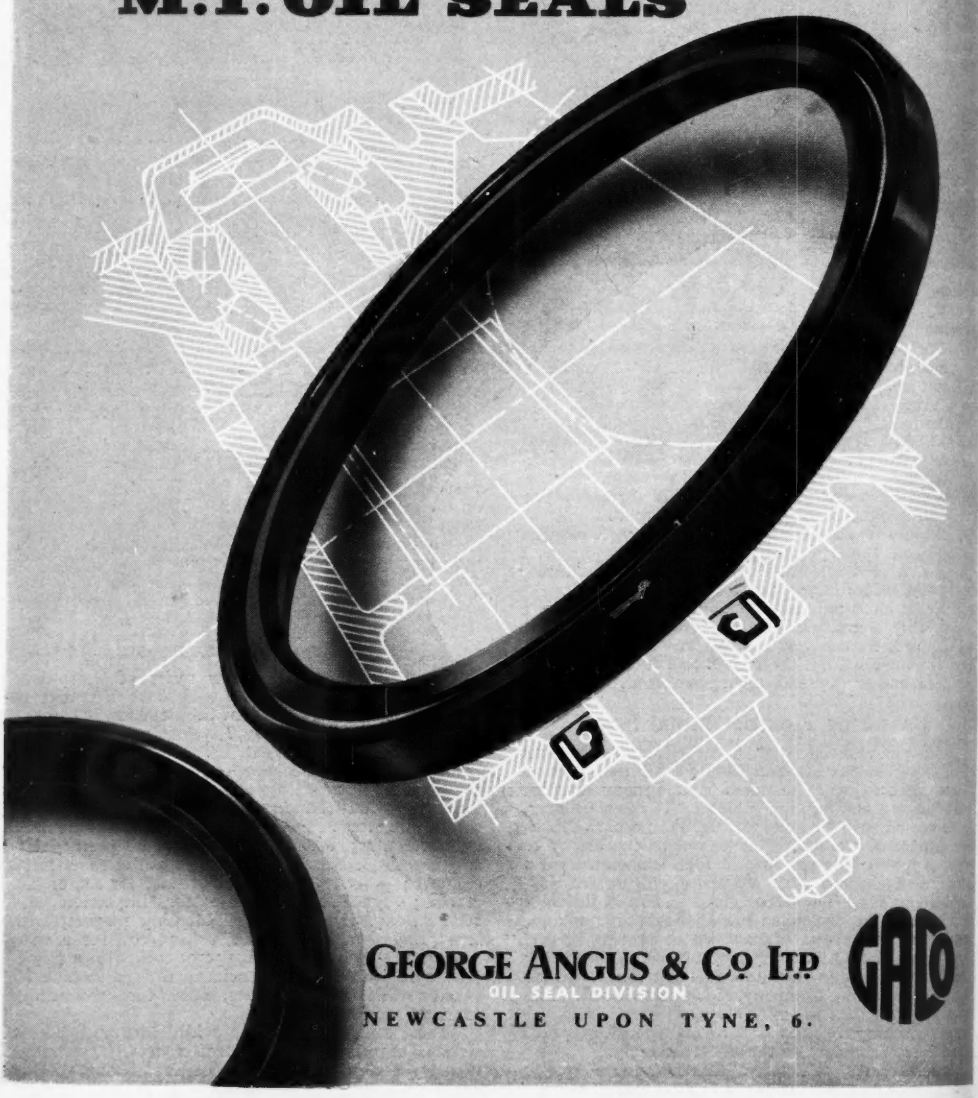

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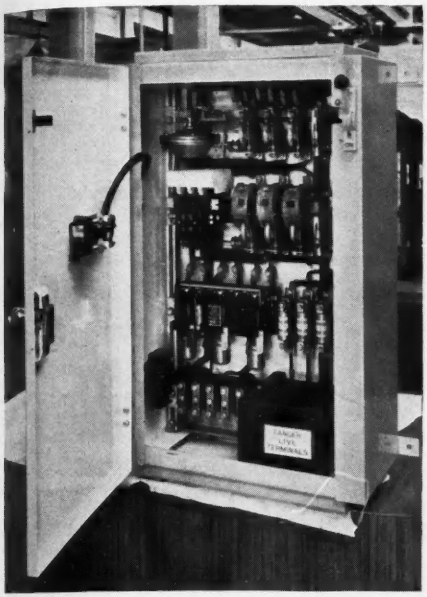


contactors can be built into motor control equipment in the direct-on, star-delta, auto-transformer, and stator/rotor types. Multi-motor control cubicles are available. The contactors are designed for a complete range of assemblies, and separate poles, auxiliary switches, etc., can be obtained for assembly into any required combination. Furthermore, they can readily be assembled into existing control boxes and into machine tools or other such equipment.

The illustration shows a star-delta starter used for medium-size squirrel-cage motors.

## Flameproof Gate-End Panel

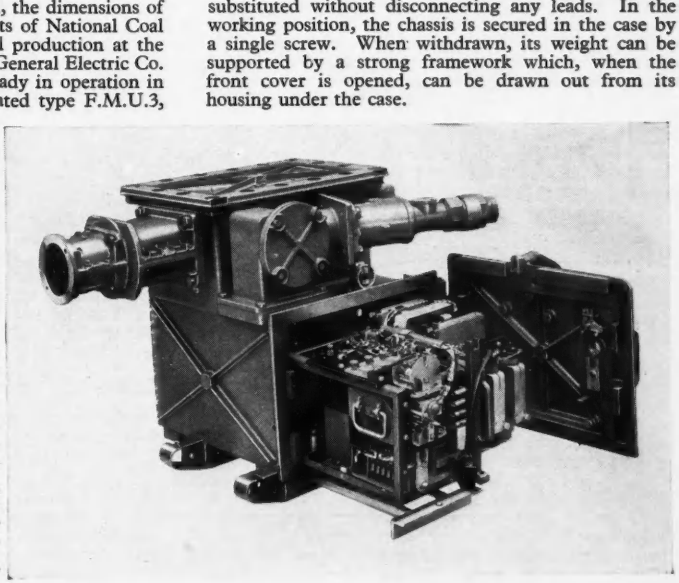
A new automatic gate-end panel, the dimensions of which comply with the requirements of National Coal Board Specifications, is now in full production at the Witton Engineering Works of The General Electric Co. Ltd., and a number of units is already in operation in British mines. This panel, designated type F.M.U.3, is primarily intended for use with motors driving coal cutters, loaders, and conveyors working at the coal face, and is designed for the control of squirrel-cage motors at voltages from 400 to 650 V with full-load currents up to 80 A. The unit is flameproof and is suitable for use in fiery mines. In addition, the control circuit and the earth-leakage electrical lockout circuit are certified as intrinsically safe.

The panel is constructed to withstand the severe operating conditions in mines. The skid-mounted enclosing case is of welded sheet steel and is divided horizontally into two compartments. The upper portion is provided with a heavily braced cover which forms the top of the unit, while the lower compartment is fitted with a hinged front cover which, when closed, is secured by means of locking dogs engaging with similar dogs on the case. The front cover is also provided with a single socket-headed fixing screw which, while not essential to the flameproof enclosure, ensures that the cover can be opened only by an authorized person. This screw also forms the interlock with the isolator, since it cannot be unscrewed until the isolator is in the " off " position ; in addition, when the door is closed, the screw must be driven home before the isolator can be closed.

The top compartment houses the 300-A busbars and a triple-pole reversing isolator. This isolator, which is of the contactor type and is fitted with series blow-outs and arc chutes, is designed to break 650 A at 650 V, 0·2 to 0·3 power factor. An auxiliary contact, connected in series with the contactor operating coil, is arranged to open before the main contacts. The operating lever, which is brought out to the front of the unit, carries a catch which engages with a gate on the front cover to prevent the isolator from being moved from the " forward " to the " reverse " position without a pause. A shrouded captive screw is provided to lock the isolator in the " off " position. A flange at each end of the upper compartment carries three main and two auxiliary bushed terminals for connections to the incoming cable or to adjacent panels.

As shown in the illustration, the lower compartment houses a withdrawable chassis, on which are mounted the triple-pole main contactor, two overcurrent relays, the core-balance and voltage transformers, and the protective relays and fuses. The chassis also carries a combined test and reset switch, a local control switch, and a sequence selector switch with an integral emergency-stop button. The switches are operated by levers mounted on the outside of the front cover. A lamp for indicating earth-leakage faults is visible through a window in the cover.

On the top of the chassis are mounted main and auxiliary isolating contacts which, when the chassis is pushed into the case, engage with spring-loaded contacts on the underside of the horizontal partition. These contacts complete the connections from the equipment on the chassis to the isolator and thence to the incoming supply, and also those to the outgoing cable through a plug-and-socket mounted externally. Thus, a chassis can be removed and a spare chassis substituted without disconnecting any leads. In the working position, the chassis is secured in the case by a single screw. When withdrawn, its weight can be supported by a strong framework which, when the front cover is opened, can be drawn out from its housing under the case.



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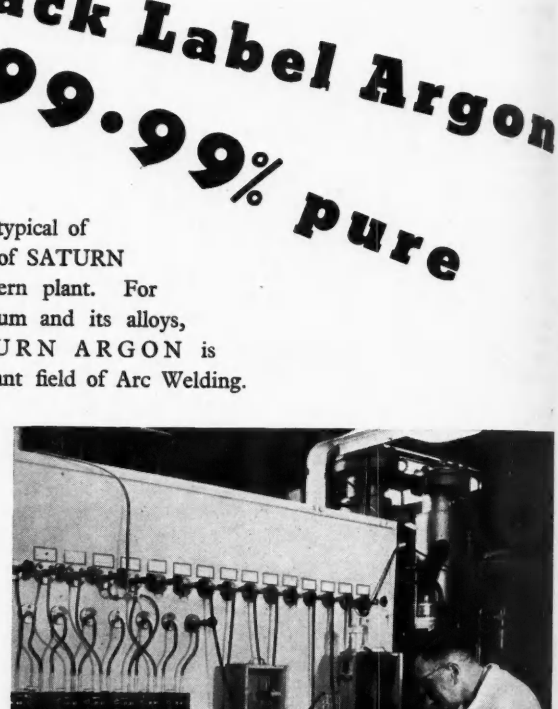

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# CLASSIFIED ABSTRACTS

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## AIRCRAFT ENGINEERING

### Design and Protection of A.C. Power Systems for Aircraft Instruments.

By O. MARKOWITZ and C. SEARS. (From *Applications and Industry* (*AIEE*), *U.S.A.*, No. 20, September 1955, pp. 209-220, 8 illustrations.)

THE role of modern military aircraft is inexorably reflected in its electrical system, which must maintain its continuity. Beyond that, the utmost of reliability and continuity is required of the electric power system supplying "safety-of-flight" items such as the gyro-horizon instrument, the turn-and-bank instrument, the fuel-quantity instrument, the engine instruments, and the fuel-flow instruments. These instruments when inoperative can easily cause loss of an aircraft.

In the past few years much concentration has been given to the design of electrical systems for flight instruments, bringing to light peculiarities inherent in the small low power-factor loads supplied through high-impedance, low-capacity power sources. In this paper are defined many of the problems and design aspects which have resulted from efforts made to increase the reliability and protection of flight-instrument power systems.

It is concluded that the following items should be considered as important during the design stages of an aircraft-instrument power system :—

(1) Power systems for safety-of-flight instruments should be designed to contain parallel sources of power as completely independent of each other, insofar as practicable to supply corresponding functionally duplicated instruments. If possible, these power sources should provide instrument power independently of the main electrical system.

(2) Idle and/or inoperative equipment should be avoided as an alternative source of power.

(3) The load analysis should be made in greater detail, so that a complete and accurate analysis of line currents in the 115-V delta system can be obtained, and every effort should be made to present a balanced 3-phase load.

(4) Application of 3-phase to 1-phase transformers should be made only after load analysis, to see if they are acceptable, considering 3-phase balance and power factor.

(5) Where inverters are used as power sources, selection should be made to assure sufficient short-circuit capacity.

(6) When fuses of the slow-blow type are applied to the design, these should be selected carefully, to avoid the mechanical unreliability inherent in certain makes and models.

(7) Corrective capacitance should not be used.

## CORROSION

### Fretting Corrosion.

By R. B. WATERHOUSE. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, October 1955, 10 pages.)

FRETTING corrosion is defined as the particular kind of damage which occurs when two surfaces in contact experience slight periodic relative movement. Examples are quoted of its appearance in very diverse circumstances, such as press-fitted hubs, riveted structures, and electrical switching gear. It can lead to loss of fit or to seizure, and is a possible source of fatigue cracks. There is as yet no clear indication whether the appearance of cracks in fretted regions is due to the pits formed acting as stress raisers, although their shape could very well produce such an effect, or whether the conditions producing fretting also cause surface fatigue. The amount of damage increases approximately linearly with increasing amplitude of relative motion and increasing normal loading. It also increases as the temperature is lowered or as the atmosphere is more corrosive.

The fretting corrosion of steel is reduced in a non-oxidizing atmosphere. There appear to be three possible processes involved, i.e., mechanical abrasion by grinding or welding, abrasion by hard particles of oxide, and continual mechanical rupture of otherwise protective oxide films. Probably all three mechanisms may be important in different cases, but most of the experimental data for fretting corrosion of steel are best explained by the third mechanism.

Preventive measures are classified according to their effectiveness in (*a*) reducing relative movement by increased friction force, such as increased normal load, electroplated metal coatings with a high coefficient of friction, and elastic inserts, (*b*) reducing friction by lubrication or low-friction inserts, such as polytetrafluorethylene, (*c*) excluding the atmosphere by means of rubber gaskets or by flooding with lubricant, (*d*) increasing the abrasion resistance of the surfaces, and (*e*) separating the surfaces.

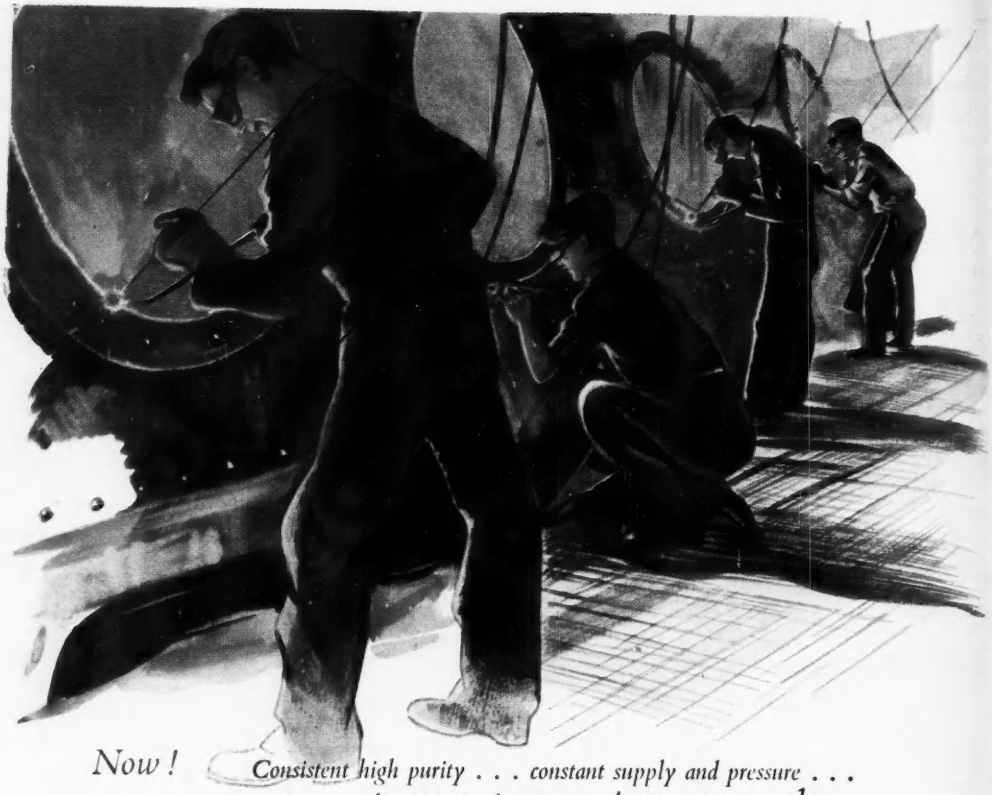
It should be understood that a measure which is a remedy in one case may aggravate the damage in another, indicating the need for careful diagnosis. In this connection, it is emphasized that fretting corrosion is a condition in which many factors play a part, the chief being the existence of periodic relative motion between the two surfaces, and the corrosive action of the environment. Before a particular remedy is tried, an analysis as detailed as possible should be made of the conditions producing the damage, so that an enlightened selection of a probable cure can be made. There is no panacea for fretting corrosion, and every example must be examined according to its merits. The methods of preventing fretting corrosion are generally applicable where fatigue is likely to occur. It should be remembered, however, that certain treatments such as anodizing are themselves known to reduce fatigue strength.

## ELECTRONIC COMPUTERS

### High-Density Tape Recording for Digital Computers.

(From *National Bureau of Standards Technical News Bulletin, U.S.A.*, Vol. 39, No. 9, September 1955, pp. 121-124, 5 illustrations.)

A method of closely packing digital pulses on magnetic tape has recently been developed. This method promises future useful application in the field of electronic computers. Such high-density storage can greatly reduce problem-solution time by providing more rapid access to information recorded on external magnetic-tape units. In a series of experiments, both continuous-current and pulse techniques were investigated to achieve densities in the range of 500 to 700 pulses per inch. Recording and reading circuitry was also developed to provide large-amplitude playback



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An integral part of many large high-speed electronic computers is some type of magnetic-tape or wire storage system which serves as an input-output means, as an external low-speed memory, or in some cases as both. Many types of mathematical problems require extensive external storage. In solving these problems relatively little actual computation is performed, but a great deal of data must be handled and assimilated by the computer. Ideally, a magnetic-tape system should supply or receive data from the machine fast enough for the computer to proceed with the solution of the problem at its normal rate. In reality, however, the maximum rate the tape can accommodate information is usually very slow compared with the machine's internal speed, because tape velocity is limited and information is commonly stored on the tape at comparatively low density. As a consequence, the majority of problem-solution time is not spent in computation, but in the performance of input-output or tape storage operations. The present investigation has been directed towards improving magnetic-tape storage technique. Such developments would permit more rapid transmission of information to the computer by increasing the number of digital pulses recorded on each inch of the tape, thereby increasing the overall efficiency of the machine.

Although the tape storage system described has not yet been completely and rigorously tested with a computer under actual operating conditions, it has been given extensive laboratory trials to determine the reliability of the reading and recording circuitry at different recording densities. For these tests the sprocket channel was recorded and used as it would be in actual operating conditions to control the recording and reading of the information channels. By recording words of information containing a known number of *ones* and *zeroes*, it was possible to obtain a fair check of the performance of the system by counting the number of *ones* or *zeroes* on playback. Without taking any precautions to prevent errors from tape flaws, several runs of one to three million digits were recorded and read at densities of 500 to 600 digits per inch without apparent errors.

## EVAPORATORS

### Heat Transfer in a Vertical Evaporator Tube on a Non-Dimensional Basis.

By E. KIRSCHBAUM. (From *De Ingenieur, Holland*, Vol. 67, No. 22, June 3, 1955, pp. Ch. 39-Ch. 48, 17 illustrations.)

IN view of the lack of generally valid fundamental data for the prediction of the heat-exchange conditions in vertical evaporators, a systematic series of tests was carried out with an evaporator tube made of pure copper, 4 m long (effective heating length 3·9 m), with internal and external diameters of 40 mm and 48 mm, respectively. The tube was externally heated by steam. The liquid to be evaporated was raised to boiling temperature in a preheater tube before passing into the main heater cylinder. A return-flow system was used, including a storage tank, condenser, vacuum pump, etc. Temperature measurements with eight pairs of thermocouples, arranged tangentially at various levels in the wall of the evaporator tube (within the heater cylinder), showed that the tube-wall temperature-distribution curve has a minimum in the upper half-portion of the tube. The vertical length of the tube can be divided into three zones, i.e., a heating zone (bottom portion), a bubble zone (middle portion) extending up to the minimum-temperature position, and a vapour zone (upper portion).

The bubble zone is greater when the apparent liquid level is reduced. The liquid temperature is highest where the wall temperature reaches its minimum values; hence, in this area the local temperature gradient between wall and liquid is reduced, and the heat-transfer coefficient is increased. The bubbles are formed in the core of the liquid. Photographs of the upper (exit) end of the tube, taken through glass ports, showed that the vapour emerges at the centre, while the separated liquid rises up the tube walls around the central vapour core. Similar results were obtained for distilled water, a solution of common salt in water, and a 30% sugar solution. In all, some 200 temperature-distribution curves were determined for various operating conditions.

The results have been evaluated as follows :—The mean tube-wall temperature $T_{WF}$ was obtained by graphical integration of measured values over the entire tube length. The temperature gradient $\theta_F = T_{WF} - T_S$ was evaluated (where $T_S$ = boiling temperature of liquid plus increase in boiling point). It was then possible to calculate the heat-transfer coefficient $\alpha_F$ [kcal/m$^2$hr°C] as $\alpha_F = Q/(F_F\theta_F)$, where $Q$ = heat effectively used for evaporation and $F_F = 0{\cdot}49$ m$^2$ = heated internal area of tube. $\alpha_F$ is a function of $\theta_F$; it is also a function of the apparent liquid level $h$, with a maximum at $h \cong 25\%$ for dilute solutions, and at $h \cong 40\%$ for a 50% sugar solution.

To obtain a formula suitable for the prediction of heat-transfer conditions, it was found convenient to introduce a modified Nusselt number $N_v$, a modified Reynolds number $R_v$ for the evaporator, a specific-weight coefficient $S$, and a viscosity parameter $Z$, defined as follows :—

$$N_v = \alpha_F\sigma/(\lambda p),\ R_v = \theta_F C_F/r,\ S = \gamma_F/(1000\gamma_D)$$
and $$Z = \eta_w/\eta,$$

where $\sigma$ = surface tension of liquid [kg/m], $\lambda$ = heat conductivity of liquid [kcal/m hr °C], $p$ = pressure [kg/m$^2$] in storage tank of evaporator, $C_F$ = specific heat of liquid [kcal/kg°C], $r$ = heat of evaporation [kcal/kg], $\gamma_F$ = density of liquid [kg/m$^3$], $\gamma_D$ = density of vapour [kg/m$^3$], $\eta_w$ = dynamic viscosity of water at 100° C and atmospheric pressure [kg sec/m$^2$], and $\eta$ = dynamic viscosity of liquid (depending on concentration of solution) [kg sec/m$^2$].

Evaluation of all the tests showed that good results can be obtained by means of the relation

$$N_v = 0{\cdot}236\ R_v\ S^{0{\cdot}5}\ Z^{0{\cdot}25}$$

For sugar solutions of approximately 40%, the use of a numerical coefficient of 0·37 (instead of 0·236) gives improved accuracy.

## FATIGUE TESTING

### Fatigue Tests and Aircraft Life Evaluation.

By T. HAAS. (From *Aircraft Engineering, London*, Vol. 27, No. 320, October 1955, pp. 334-337, 7 illustrations).

THE method used at present in the fatigue testing of aircraft structures or their components, involving the application of cycles of constant stress amplitudes of a magnitude considered to be the most damaging, is based on the cumulative damage rule. Present indications are that the cumulative damage rule underestimates the effect of stress cycles of low amplitudes, which comprise about half of the total number of cycles within the spectrum to failure.

In order to clarify the position, important approaches to the problem have been analysed with a view to correlating these on a largely experimental basis. The statistical concept has been extended to all aspects of the problem, so as to enable comparisons to be based on a given value of probability of failure, defined as the proportion of the number of specimens failed to the total number tested. Thus, instead of a single *S-N* curve, a family of curves (*P-S-N* curves) is obtained, each of which indicates a definite probability of failure *P*. The same process is applied to spectra to failure obtained from service endurance tests.

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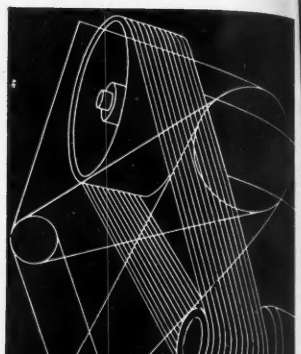

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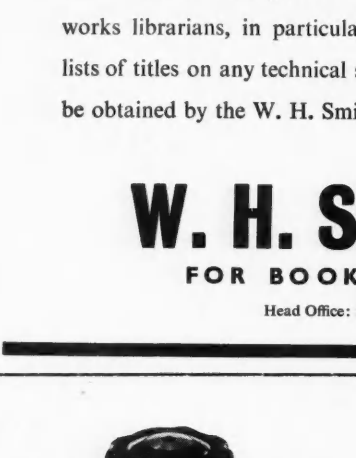

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A summary of the proposed process of co-ordination of existing approaches to the problem is as follows :—

(1) Both stress and endurance remain unfactored throughout the comparison of analytical and experimental methods. The final estimate of life is factored down according to agreed airworthiness requirements.

(2) All comparisons refer to probabilities which can be obtained experimentally. Where analytical or graphical extrapolation is obtainable, the value of probability adhered to is to be in accordance with the accepted failure rate.

(3) The cumulative damage rule is applied to the *P-S-N* curves, whereby the cycle ratios are in accordance with the chosen programme cycle used in service endurance tests, which are then compared with the cumulative damage rule. A correction factor is thus obtained for the rule.

(4) The final comparison employs the method used at present, but replaces the flight spectrum with the spectrum to failure resulting from a service endurance test. The comparison is repeated to embrace all experimental probabilities.

If, in carrying out the proposals of this paper, the limits of validity of the cumulative damage rule and possible correction factors could be established, and an interpretation of the results of load cycles of constant amplitude in terms of the service endurance test obtained, then a practical basis would be available for correlating conventional fatigue tests with programme loading. This would also lead to a better understanding of the numerous factors influencing the endurance life of structures. However, should the method of correlation prove that the co-existence of service-endurance testing with the method at present most widely adopted has no significance, it would lead to the acceptance of the more rational method.

## MATERIALS TESTING

### The Value of the Notch Tensile Test.

By J. F. Baker and C. F. Tipper. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, October 28, 1955, 13 pages, 9 illustrations.)

The object of this paper is to demonstrate that the simple notched tensile test bar, which has emerged as a result of the investigations into brittle fractures in mild steel carried out in the Engineering Department, Cambridge University, can be a reliable test of service performance. It not only gives direct correlation with service, but it may also be used to predict the behaviour of a material in a more complicated form.

The good measure of agreement obtained during the investigation into a number of service casualties is proof that the criticisms levelled at the test are invalid and that the initiation and propagation mechanisms, first put forward tentatively in Report R.3 of the Admiralty Ship Welding Committee, have been substantiated. No claim is made that it gives information with respect to the stress levels for initiation or propagation of fractures, but it is possible to deduce from the experimental results whether a normal or brittle fracture is likely to be initiated at the temperature of operation.

The designer of a fabricated structure is not comforted by the information that a brittle fracture would not propagate if the working stresses did not exceed some limit. Every designer is now aware that the stress distribution deduced from his approximate design calculations is very different from that which really exists. Whether welding or riveting is used, high stresses will always occur, even under low loads. Were a designer forced to use a material which was susceptible to brittle fracture when the nominal stress exceeded some value, he would have to change the form of his design radically. It would be impossible to use relatively thin load-bearing plates, as in ships and storage tanks.

Efforts to remove the gross defects of design and welding technique, which were responsible for many of the earlier ship casualties, have reduced their number. The complete collapse of two oil-storage tanks and the development of cracks during construction in other steel structures show that the risk is not past. Moreover, the interesting account of brittle failure of non-ship steel-plate structures recently compiled by Shank has brought forward examples in both welded and riveted structures, extending over many years up to the present day.

It is difficult to see what further steps can be taken to minimize the possibility of future fractures, other than by an improvement in material; the use of a reliable test is a first step towards this end. It is considered that the simple notched tensile test-piece described in this paper fulfils all requirements; it is easily prepared, can be tested in any tensile testing machine, and gives all the information necessary for assessing the notch ductility of the material; furthermore, it shows good correlation with service performance.

## PUMPS

### An Experimental Study of Air - Entraining Vortices in Pump Sumps.

By D. F. Denny. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, November 4, 1955, 13 pages, 23 illustrations.)

It is generally accepted that the performance of a pump can be greatly affected by the design of sump from which it draws water. There are two aspects to this problem. Firstly, swirl in the sump leads to rotation of the water in the suction pipe, which may impair the performance of the pump, and this is particularly important with axial-flow pumps and centrifugal pumps with a high specific speed. Secondly, severe swirl sometimes leads to a fully developed vortex having a hollow core, through which air is drawn into the suction inlet. Apart from the effect of the air itself, which tends to lower the delivery of the pump, such vortices are unstable and give rise to unsteady swirl flows in the pipe and to fluctuating loads on the pump bearings.

In this paper, the factors affecting the formation of air-entraining vortices in sumps are enumerated, and their relative importance assessed from experiments with a number of different sumps. It is established that vortices are caused by rotation of the mass of water within the sump, arising primarily from the entry conditions. Their severity, measured in terms of the minimum safe submergence to avoid air entrainment, was also found to depend greatly on the velocity in the suction inlet; air entrainment rarely occurred below a velocity of 2 fps, while above 15 or 20 fps the severity of the vortices did not increase substantially.

The shape and disposition of the suction inlet only slightly affected the vortices, but sump boundaries were found to reduce appreciably the tendency for vortex formation when closer than 8 diameters to the suction pipe; with the walls very close to the pipe, vortices did not occur. Small sumps may thus be more satisfactory than spacious sumps.

Tests with scale models of existing or proposed pump installations are described, and for one sump, where vortices formed within the working range, it is demonstrated that suitably placed boundary walls would be considerably more effective in preventing vortices than modifications to the suction inlets.

Measurements of the quantity of air drawn into the pump through a vortex showed that air entrainment of this type could seriously impair pump performance, and that severe vortices could lead to depriming of pumps operating with suction lift.

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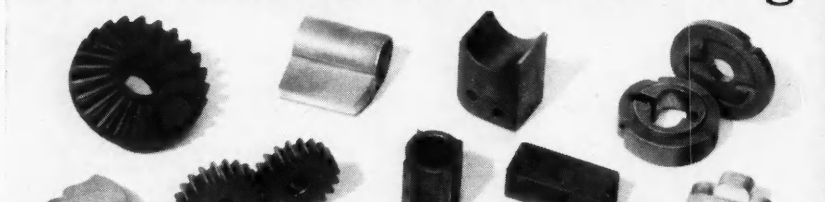

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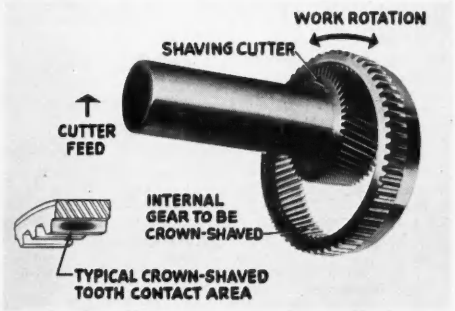
# New Materials, Processes, and Equipment

## INTERNAL GEAR-SHAVING MACHINE

Designed to anticipate the need for greater precision in the shaving of internal gears, with a reduction in shaving time, and to give a broader range of application, with greater ease of operation, the new "Red Ring," model GCR, gear-shaving machine developed by the National Broach & Machine Company, of Detroit, Michigan, will provide precision shaving of all spur or helical internal gears, 3 to 12 in. pitch diameter, up to 4 D.P., with face widths up to 2½ in. The machine operates on an automatic and selective feed cycle and provides the opportunity to use a new rapid plunge-cut shaving cycle in addition to conventional shaving. Crowning is optional with plunge-cut shaving.

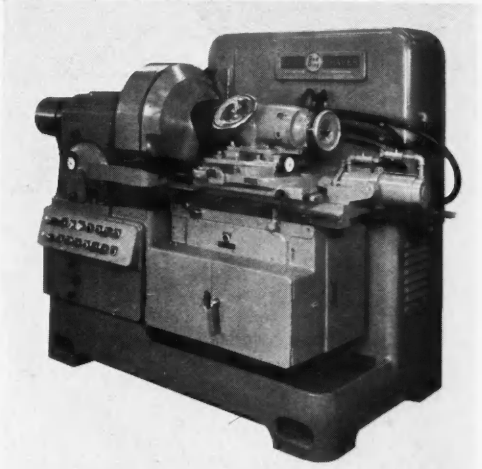
In the new machine, the work in the shaving position drives the cutter, while the axes of the cutter and work gear are set in accordance with the crossed-axes principle of gear shaving, as shown below. The cutter is reciprocated across the face of the work gear teeth, except in plunge-cut shaving. As each reciprocal stroke is completed in conventional shaving, the cutter is fed one increment into the work gear, unless a dwell is desired. Feed and reciprocation of cutter during the shaving cycle are both performed by precision lead-screw action.

For plunge-cut shaving, the cutter must be at least as wide as the work gear and must be serrated differentially. Neither cutter nor work gear is reciprocated in plunge-cut shaving. The cutter is fed into the work by increments, down to full depth, and is allowed to idle at full depth for a given number of revolutions before being automatically withdrawn.




The machine has a pivoted work-head, the purpose of which is to facilitate the loading of wide-face gears and those having integral shafts. The work-head swings 30 deg. above the horizontal shaving position. Pivoting action and locking are pneumatically actuated and are also interlocked with the cutter controls, to eliminate the possibility of cutter damage. When taper-shaving, the work-head may be locked in positions up to 1½ deg. above or below horizontal. Any type of manual or air-actuated work-holding device may be used. The work-head spindle is driven by its own motor through worm gearing and change gears.

With the work gear clamped in the shaving position, the cutter slide is rapidly advanced by means of a pneumatic cylinder to a point just short of contact between cutter and work. Meshing is accomplished by means of the handwheel on the front of the cutter head, while the cutter is indexed by the handwheel at the right end of the cutter spindle. Generally, the indexing handwheel is not used, as the lead-in incorporated in the cutter will automatically mesh the cutter and work. The same pneumatic cylinder retracts the cutter slide to its unloading position on completion of the shaving cycle. Thus, the minimum of physical exertion is required from the operator.



The cutter-spindle axis can be swung 15 deg. either way from centre, to accommodate the desired crossed-axes setting. A selected number of cutting strokes may be used with or without a selected number of idling strokes. Up-feed of any selected amount can be used for each individual cutting stroke under complete automatic control. At the end of the cycle, the cutter automatically returns to the proper backlash position for unloading and reloading. The amount and accuracy of up-feed is governed by a master cam, which serves as a stepped gauging device. The cam itself exerts no actuating force. Two such cams, similar except for the amount of feed increments, are included on the sequence plate of the feed unit, one on either side. Each knee movement so controlled is fast, positive, and precise. The up-feed control mechanism is housed in a closed cabinet at the front of the knee. An observation window permits the operator, at any time, to read a circular scale which indicates the amount of up-feed for each cutting stroke. The cabinet may be locked to prevent any unauthorized changes in the shaving cycle.

The work gear is loaded and clamped manually or by air, depending on the chuck. The cutter-head assembly is advanced pneumatically and the cutter meshed with the work gear by means of the hand-wheels previously mentioned. The automatic shaving cycle is started by a push-button control. At the end of the last stroke the machine stops and the work gear is unloaded.

## OPTICAL-COORDINATE JIG-BORING MACHINE

Designed to complete their range of OPCO and OPTA coordinate jig borers, a new machine, with vertical and horizontal boring heads, has been introduced by Hermann Kolb Maschinenfabrik G.m.b.H., of Cologne, Germany, and is distributed in Great Britain by Stanley Howard Ltd., of Birmingham.

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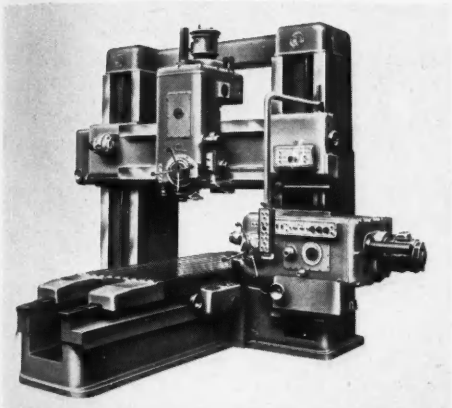
incorporating a reliable optical system, with glass scales and a diascopic screen, this machine enables an operator, by means of the light-gap method, to set the table or the spindles with an accuracy of 0·001 in. With the horizontal boring head, two planes of 79 × 47 in. and 79 × 39 in. respectively can now be measured and machined in one chucking.

The machine is suitable for the production of large jigs and fixtures and for the machining of frames and small batch components without jigs. Three different versions of this machine are being constructed, i.e., with vertical and horizontal boring heads, with a vertical boring head, and with a horizontal boring head and only one upright. Thus, with the bed and table as basic elements, three different machine types are available.



The bed is a robust casting with ample ribbing. The long table runs on balls on hardened guides, which are of square form, in order to carry the load without a lateral component and to transmit the pressure directly to the bed. The table drive and its locking mechanism are mounted inside the bed. A channel for coolant surrounds the table surface, and a precision glass scale, in a special, longitudinally adjustable mounting, is fitted, the whole being well protected inside the table.

The boring heads are equipped with gearboxes for 24 or 36 spindle speeds and with a feed gear for 18 feeds. All gears are hardened and ground, and are driven by a flanged motor *via* a reversible multiple-disc clutch, actuation being by electrohydraulic preselection. The hardened quill, which can be locked for milling operations, can be moved by hand, by automatic feed, and by rapid traverse *via* electromagnetic clutches. The boring spindle, machined from alloy steel, runs in carefully selected precision rolling bearings.

The uprights are bolted to the bed, provision being made for correct alignment. The lead-screws are firmly held at the top and at the bottom of the uprights. The drive-nuts for the cross-rail and the horizontal head are operated by a worm and worm-wheel. A motor, electrically interconnected with the vertical-traverse drive, automatically locks and unlocks the cross-rail. For operating the table and boring-head movements, d.c. motors are used, providing infinitely variable speeds between 1 and 8 in. per min. The rapid traverse has a constant speed of 59 ipm, and the horizontal head 23 ipm. Table locking is effected by a push-button-controlled motor, while boring-head locking is operated automatically by means of an oil pump.

The optical installations on the table and boring heads are so arranged that the operator can observe the screens from one position. The screen for the table movement is mounted on the bed, while the other screens are attached to the boring heads themselves. The glass scales are made from a special optical glass, the thermal expansion of which is the same as that of cast iron. These scales carry on their surface calibrated hair-lines which, by means of the optical system, are projected, with a suitable magnification, onto the focusing screen.

Mechanical movements can be arrested by means of adjustable trips. In the case of repetition work, these trips can be set in such a way as to permit establishing a predetermined programme for the rapid and feed movements. Fine adjustment is then effected by hand.

## MINIATURE pH METER

The latest addition to the range of laboratory and industrial pH meters manufactured by Electrofact Limited, of London, W.1, is their type 40 A meter, in which, by the use of sub-miniature valves and hearing-aid batteries, a two-stage d.c. amplifier has been compressed into a compact instrument for on-the-spot pH measurements, with a range of 1 to 13 pH, or 0 to 14 pH by buffer control.

Notwithstanding its reduced dimensions, the instrument, which measures only $8\frac{7}{8} \times 4\frac{5}{8} \times 3\frac{1}{4}$ in. high and weighs 4 lb, features such advantages as a large (3-in.) scale, provision for housing within the case a combined glass-calomel electrode and a thermometer, a high-impedance input circuit, and a specially screened electrode input. Absolute accuracy is higher than $\pm 0{\cdot}2$ pH, reproducibility is better than $\pm 0{\cdot}1$ pH, and discrimination is 0·04 pH.

Operation is extremely simple :—After switching on and setting the temperature control, the pointer is set to zero by the appropriate control, and the meter is then calibrated with a buffer solution. No other adjustments are necessary, and no loss of time from warming-up is incurred. A wide choice of electrodes is available and, as a result of the use of sub-miniature valves, battery consumption is kept very low, averaging about 1000 hr continuous use for the H.T. batteries and 250 hr for the L.T. batteries.

## INTERNAL GRINDING MACHINE

A new internal grinding machine, type 2018/3, designed for small and medium-sized workpieces, including tungsten carbide dies, etc., and suitable for the toolroom and general production, has been added to their range by Rudkin & Riley Ltd., of Aylestone, Leicester. Attachments are available for external grinding, coolant supply, fine parallel-bore lapping, and radial grinding. In addition, a rapid-clamping lever for mass production can be supplied.

The well-proportioned work-head, which incorporates cross-traverse micro-feed, can be swivelled to grind tapered workpieces up to 30 deg. inclusive on the standard machine and up to 120 deg. with a modified work-head, where required. A slide bar is incorporated in the work-head to carry the diamond tool for dressing the grinding wheel, and also to act as a steady for grinding between centres. For wet grinding, a protective cowl is fitted to enclose the chuck and workpiece completely. The grinding-spindle unit on the grinding carriage can be reversed, thus offsetting the grinding spindle $2\frac{1}{2}$ in., to allow for external grinding in conjunction with a support for centered workpieces extending from the slide bar. A magnetic filter is available for use with the coolant supply, and the coolant tank and pump are housed in the cabinet-stand supplied with the machine.

The machine is fitted with automatic reciprocating traverse of the grinding carriage, giving an adjustable stroke of 4 in. maximum. The reciprocating mechanism is driven from a separately controlled $\frac{1}{3}$-hp motor and is easily and quickly adjusted for the required length of stroke. An alternative hand-operating arrangement is also fitted, with an adjustable stop to determine the

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forward stroke when the grinding carriage is operated manually; the manual grinding operation permits an additional 2 in. grinding length, to give a total of 6 in. To ensure smooth traverse the grinding carriage operates in a V-bed and ball bearings. The work-head will accommodate self-centering chucks (6 in. maximum) or collets, where preferred.

## PRESSURE PAINT CONTAINER

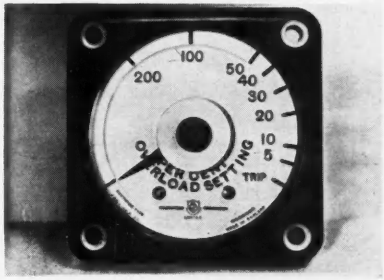
A 2-gallon pressure paint container of entirely new design and construction is announced by Alfred Bullows & Sons Limited, of Walsall, Staffs. The shell of the container, as well as the cover, is in the form of a high-tensile aluminium-alloy diecasting, and replaces the conventional galvanized welded mild-steel shell. As a result, there is a substantial saving in weight and, most important, a perfectly smooth surface both inside and out, making cleaning of the container a very simple matter. This is an important advantage whenever it is required to use the container for a variety of different coloured paints.

The cover is held in position by forged-steel " C " clamps and handscrews, enabling it to be quickly and easily removed. The feed pipe is of duralumin. This means that all parts in contact with the paint are of aluminium alloy or stainless steel. There is no brass or mild steel used internally at all. The container will also be available with a galvanized mild-steel shell, for use with materials corrosive to aluminium.

The container is available with or without a pressure-reducing valve unit, which is flange-mounted on the cover and houses the shrouded pressure gauge. It has a built-in safety valve with an easing ring, so that it is used as a blow-off valve, and is non-adjustable. All containers are designed for a maximum working pressure of 50 psi and are hydraulically tested to 100 psi.

## OVERLOAD CONTACT-MAKING AMMETER

Newly developed by Crompton Parkinson Ltd., of London, W.C.2, is a simple device which affords reliable overload protection for electrically driven machines. The applications for such a device are numerous, particularly with machine tools which frequently necessitate the provision of a warning system, or some form of cut-out protection, in case the power load reaches a value beyond which damage is likely to occur. The new device consists basically of a sensitive ammeter provided with a pair of contacts which close at full-scale deflection to operate an external relay. This relay can be utilized to operate a warning system or a mechanism to stop operation of the machine. The instrument is usually supplied with a dial calibrated in " percentage overload setting " to give a visual indication of the overload causing the contacts to close.




In use, the instrument is connected to the secondary winding of a variable-ratio current transformer, the primary of which is connected to take the operating current of the machine being controlled. By a simple hand adjustment of the current transformer, the ammeter can be set to the appropriate overload value, thus avoiding the use of an adjustable contact in the instrument. Obviously, it is a considerable advantage under machine-shop conditions to apply any required adjustment to the relatively sturdy member of the transformer, rather than to the delicate mechanism of the ammeter. Another feature of the arrangement is that it permits the fixed contact in the ammeter to be located at a point corresponding to full-scale deflection, so that the complete range of the instrument can be ulilized and maximum accuracy obtained.

A typical application for the device is in the automatic control of deep-drilling machines, the drills of which are likely to bind and break due to accumulated chippings, unless periodically withdrawn. By using the new device, the withdrawal mechanism would be set in action only when a predetermined overload occurs, e.g., 10% above normal. The transformer would be set so that the ammeter indicates such an overload, the contacts closing and so operating the relay actuating the drill withdrawal mechanism when the overload actually occurs, i.e., at full-scale value on the instrument. The drill, therefore, would not be withdrawn until strictly necessary to avoid breakage. Other applications are, of course, possible.

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# NEWS OF THE MONTH

## PERSONAL

**Mr. W. K. G. Allen, M.I.Mar.E., A.M.I.N.A.,** chairman and joint managing director of W. H. Allen, Sons & Co. Ltd., has been elected President of the British Engineers' Association, 32 Victoria Street, London, S.W.1, in succession to **Mr. H. S. Broom, M.B.E., B.Sc., M.I.Mech.E.,** who has been elected honorary treasurer. **Mr. E. W. Thompson, M.A., J.P.,** chairman and managing director of John Thompson Ltd., has been elected vice-president.

**Mr. A. E. Andrew, A.M.I.Prod.E.,** has been appointed superintendent of the main production department of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17, to succeed **Mr. A. J. Leslie,** who will continue to assist the director of manufacturing on special problems.

**Mr. Stuart L. M. Barlow, A.M.I.E.E., M.Amer.I.E.E.,** has been elected a non-executive member of the Board of The Electric Construction Co. Ltd., Bushbury Engineering Works, Wolverhampton.

**Mr. W. H. Batchelor** has been elected to the Board of Perry Barr Metal Co. Ltd., Great Barr, Birmingham, 22A, as commercial director.

**Mr. John Boyle, D.Sc., B.Sc., A.M.I.C.E.,** whose ancestor is known to all students of gaseous matter through Boyle's Law, has been appointed joint chief engineer to Ind Coope & Allsopp Ltd., Burton-on-Trent. He succeeds **Mr. J. H. Wardle,** who is retiring on medical advice, but will be retained in consulting capacity.

**Mr. A. C. Brearley, B.Met., F.I.M.,** has joined the Board of Catton & Co. Ltd., Yorkshire Steel Foundry, Leeds, 10, as technical director.

**Mr. R. T. Bromfield** has been appointed general manager of Invicta Electrodes Ltd., Bilston Lane, Willenhall, Staffs., a subsidiary company of Rubery, Owen & Co. Ltd.

**Mr. A. S. C. Chattey,** managing director of A.C.V. Sales Ltd., has been elected to the Board of A.E.C. Ltd., Southall, Middlesex.

**Mr. R. J. Cochran** has been appointed sales manager, Plant Department, and **Mr. J. Dyson, B.Sc.(Eng.), A.M.I.E.E.,** has been appointed sales manager, Transformer Department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.

**Mr. N. A. Deighton** has been appointed chief engineer (Sales), and **Mr. J. R. Fish** has been appointed chief engineer (Design) of J. and H. McLaren Ltd., Leeds.

**Mr. J. M. Delapena, A.S.M.A.,** has been appointed home and export sales manager of Abwood Machine Tools Ltd., Princes Road, Dartford, Kent.

**Mr. W. D. Farrington, B.Sc.(Eng.), A.C.G.I., A.M.I.Mech.E.,** has been appointed chief inspecting engineer, Crown Agents for Oversea Governments and Administrations, in succession to **Mr. J. W. Norris, C.B.E., A.C.G.I., A.M.I.C.E., A.M.I.Mech.E.,** who retired but remains in service in an advisory capacity.

**Mr. R. J. Foster, D.F.C., A.F.C.,** has been appointed general manager of British Oxygen Aro Equipment Ltd., formed by the British Oxygen Co. Ltd. and the Aro Equipment Corporation of America.

**Dr. W. R. Hawthorne, M.I.Mech.E., F.R.Ae.S., F.R.S.,** Professor of Applied Thermodynamics at the University of Cambridge, has been appointed Jerome Clarke Hunsaker Professor of Aeronautical Engineering at the Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A.

**Mr. P. L. Jones, M.C.,** director of Swan, Hunter, and Wigham Richardson Ltd., Newcastle-upon-Tyne, has been elected chairman, and **Mr. James Ferrier,** chairman and managing director of Rankin & Blackmore Ltd., Greenock, vice-chairman, of the National Association of Marine Engine Builders.

**Mr. D. Jubb** has been appointed technical manager of Modern Engineering (Bristol) Ltd., Emery Road, Brislington Trading Estate, Bristol, 4.

**Sir Bernard Keen, D.Sc., F.Inst.P., F.R.S.,** has been appointed scientific adviser to Baird & Tatlock (London) Ltd., 14-17 St. Cross Street, London, E.C.1.

**Mr. Norman Lee** has been appointed service manager of the British Materials Handling Division of The Yale & Towne Manufacturing Company, Wednesfield, Wolverhampton.

**Mr. A. D. Mackay** has resigned as managing director of The Bergius Co. Ltd., owing to his other responsibilities with Associated British Engineering Ltd., 9/10 Cavendish Square, London, W.1, and has been elected deputy chairman. **Mr. W. A. Greenhill** has joined the Board and has been appointed managing director.

**Mr. A. M. A. Majendie, M.A., A.F.R.Ae.S., F.I.N.,** of Smiths Aircraft Instruments Ltd., London, N.W.2, has been elected President of the Institute of Navigation.

**Sir Herbert Manzoni, C.B.E.,** engineer and surveyor of the City of Birmingham, has been elected chairman of the General Council of the British Standards Institution. **Sir Roger Duncalfe,** chairman of British Glues and Chemicals Ltd., has been re-elected President and **Mr. John Ryan,** vice-chairman of the Metal Box Co. Ltd., who has completed his three-year period as chairman of the General Council, has been elected vice-president. **Sir Stanley Rawson,** vice-chairman of John Brown & Co. Ltd., has been elected chairman of the B.S.I. Engineering Divisional Council. He succeeds **Mr. S. J. Harley,** chairman of the Coventry Gauge & Tool Co. Ltd., in directing the largest individual section of B.S.I.'s work on both national and international standardization.

**Dr. A. Parker, C.B.E.,** director of Fuel Research, has been installed as chairman of the council of the Royal Society of Health, 90 Buckingham Palace Road, London, S.W.1.

**Dr. Bernard Raistrick,** research manager, **Mr. J. P. A. Macdonald,** chief engineer, and **Dr. J. Craik** have been elected to the Board of Scottish Agricultural Industries Ltd., Edinburgh.

**Mr. Kenton Redgrave, M.C., M.I.Mech.E.,** deputy chairman and managing director of Russell Newbury & Co. Ltd., Dagenham, Essex, has been elected chairman of the British Combustion Engine Manufacturers' Association Export Committee, in succession to **Mr. J. P. Ford.**

**Mr. G. S. Samways,** until recently joint managing director of The Metal Box Co. Ltd., has joined the Board of Sanderson Brothers and Newbould Ltd., Newhall Road, Sheffield. Mr. Samways is a founder member of The British Institute of Management.

**Mr. John Shireff** has been appointed vice-president of Johnson Matthey & Mallory Ltd., the Canadian associate of Johnson, Matthey & Co. Ltd.

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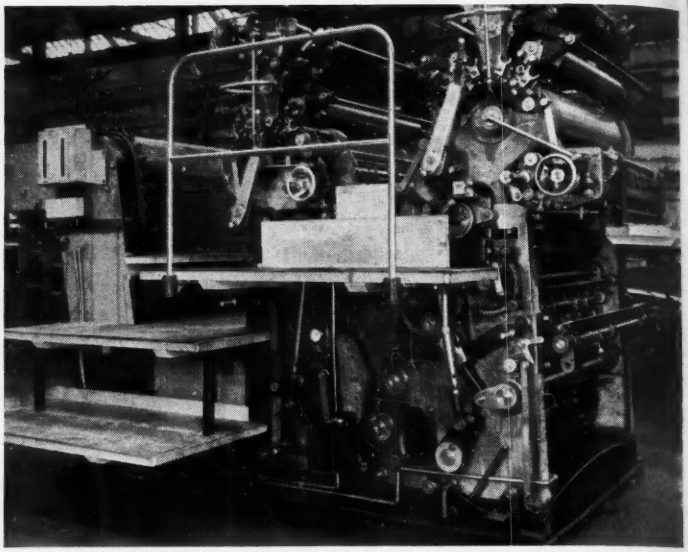

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In branches of industry where the product must be kept scrupulously clean—such as Food, Fine Textiles or Printing—the problem is to avoid over-lubrication without risking under-lubrication.

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The ' Bijur ' is one of the wide range of Tecalemit lubrication systems for oil or grease used throughout industry.

A Tecalemit technical representative will gladly supply full information on the ' Bijur ' system and its installation.

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**Mr. W. Strath, C.B., M.A.,** has been appointed full-time member of the United Kingdom Atomic Energy Authority. Sir **A. Rowland Smith,** chairman of Ford Motor Co. Ltd., and Mr. **C. F. Kearton, O.B.E.,** a director of Courtaulds Ltd., have been appointed part-time members.

**Mr. R. D. Taylor** has taken up his duties as London branch manager of the Brush Electrical Engineering Co. Ltd., Loughborough. **Mr. G. M. Ingram** has been appointed manager of the Sheffield branch and **Mr. D. P. Engert** has been appointed manager of the Ipswich branch office of the company.

**Mr. J. L. Thompson, M.Sc.,** has been appointed manager of the Square D Co. Ltd., 100 Aldersgate Street, London, E.C.1.

**Brigadier L. de M. Thuillier, O.B.E., A.D.C.,** has been appointed director of telecommunications, War Office, London, S.W.1.

**Major-General L. N. Tyler, C.B., O.B.E., B.Sc., R.E.M.E.,** director of mechanical engineering, Middle East Land Forces, has been appointed commandant of the headquarters base workshop group, R.E.M.E., Chilwell, Nottinghamshire.

**Mr. J. M. Willey, A.M.I.E.E., M.I.W.,** general manager of Murex Welding Processes Ltd., Waltham Cross, Herts, has been elected to the Board of the company.

**Mr. A. Williams-Gardner,** sales director, **Mr. John Mitchell,** manager of the Sparkler Filter Division, and **Mr. H. Houlker,** manager of the Industrial Dryer Division, have been elected to the Board of L. A. Mitchell Ltd., 37 Peter Street, Manchester, 2.

## P. G. CORIN, M.A., M.Inst.C.E.

It is with profound regret that we have learned of the recent death on 14th October of Mr. P. G. Corin, joint managing director of Henry Berry & Co. Ltd., hydraulic engineers of Leeds.

Phillip Grosvenor Corin was born on 14th August, 1897, and served in the Great War of 1914-18.

On demobilization, he went to Cambridge and graduated as an M.A., showing early leanings towards the engineering profession, which he was to adopt as his life career. He joined the technical staff of the I.C.I. and continued with them until 1935, when he joined Henry Berry & Co. Ltd., as technical director, becoming joint managing director in 1952.

For the past 20 years his experience and technical knowledge has helped very considerably towards the prosperity of the firm. His loss will be much missed by his colleagues, both as a friend and for his technical advice.

Mr. Arthur Walker, who was joint managing director with Mr. Corin, has now been appointed sole managing director of Henry Berry & Co. Ltd.

## NEW OXYGEN PLANT FOR LINCOLNSHIRE

A new piped oxygen plant scheduled to begin production in 1957 at Scunthorpe is expected to inspire a number of changes in the Lincolnshire coast steel industry.

Scunthorpe has been associated with the iron and steel industries for a century and in the past ten years production of iron has increased more than 60 per cent and production of crude steel has nearly doubled. About 1·7 million tons of iron and two million tons of crude steel a year is the output from the Scunthorpe area.

With the growth of the steel industry many new processes have been developed in which oxygen is used for cutting and for removing surface defects from crude steel and the like. In the last few years methods have been introduced for the application of oxygen in the actual steel making processes. In the case of Scunthorpe the millions of cubic feet of oxygen used by the steel industry has been brought from the Sheffield area—50 miles away. With the increasing usage, particularly in the steel furnaces themselves it has become appropriate to set up oxygen manufacture locally with a plant of the largest capacity coupled with pipelines distribution.

The plant will be what is known as the tonnage type, i.e., for manufacture on a large-scale as distinct from the normal industrial magnitudes and suitable for distribution by pipeline. The process is to one of the British Oxygen Company's own Rescol design.

Tonnage oxygen, as the iron and steel manufacturers anticipate, will reduce oxygen costs which will be reflected in greater and cheaper steel output.

At Scunthorpe the initial installation will comprise a plant with a productive capacity of 200 tons of oxygen a day—or about 36,000,000 cubic feet a week.

The site selected by the British Oxygen Company for the new oxygen works is in the Warren Road area of Scunthorpe—almost mid-way between the Normanby Park steel works and the Appleby, Frodingham, Redbourne and Firth Brown group of steel works.

## SAFETY CODE FOR INDUSTRIAL POWER TRUCKS

At the beginning of this year the Industrial Truck Manufacturers' Association published details of the design standards to which their members subscribed in the production of industrial trucks for internal factory use.

Such trucks included fork lifts, fixed and elevating platform equipments, straddle carriers, tractors, pallet trucks and a host of ancillary units. The booklet not only gives details of the design considerations but also embodies interesting data on the steps which should be taken for its efficient operation, including a section devoted to safety do's and don'ts for the operator.

A glossary of standard terms used by the industry is a feature of the booklet, of which some 15,000 copies have already been dispersed in this country and overseas.

Copies may be obtained from the Secretaries, 94/98 Petty France, London, S.W.1, price 2/6d., post free.

## "DROP FORGINGS IN ALLOY STEELS"

Produced by the Photographic Section of the Firth-Brown Research Laboratories, the new colour film "Drop Forgings in Alloy Steels" admirably covers the wide field of activities of The Firth-Derihon Stampings Ltd., of Sheffield and Darley Dale, ranging from the production of selected types of drop forgings, from the original steel bar to the finish-machined component.

The importance of special forging-quality steels is well emphasized by a series of shots covering gas-turbine discs and the factors affecting die design, and includes the forging of "cut-pieces," followed by drop forging, heat treatment, works and laboratory testing, and inspection by non-destructive methods. The latest etch-inspection methods in the production of propeller-turbine aero-engines are also featured. Other scenes deal with the construction of helicopter-rotor assemblies, the drop forging of connecting rods for piston engines, the machining and assembly of a radial sleeve-valve aero-engine, and the building and testing of a large marine diesel engine.

A particularly interesting section of the film covers the forging of gas-turbine blades manufactured from Nimonic nickel-based alloys. The commercial application of these blades, as well as those made of special high-chromium steels, is well illustrated in a 52-000-kW steam turbo-alternator, together with two gas turbo-alternators of 900 and 2500 kW respectively.

The final sequences of the film give examples of specialized uses of drop forgings in the manufacture of cream separators, cotton-ginning machines, gate valves, etc., and in gear production, including back-axle differential crown wheels and pinions and axle trunnion sockets.

Copies of this film (16 mm, sound, 1200 ft, running time 33 min) are available on free loan on application to the Company.

## "A CENTURY OF ENGINEERING TOOL DEVELOPMENT"

Shot principally in the works of the English Steel Tool Corporation Ltd. (a subsidiary of the English Steel Corporation Ltd., Sheffield), the new 16-mm colour film, "A Century of Engineering Tool Development," produced by the English Steel Corporation's

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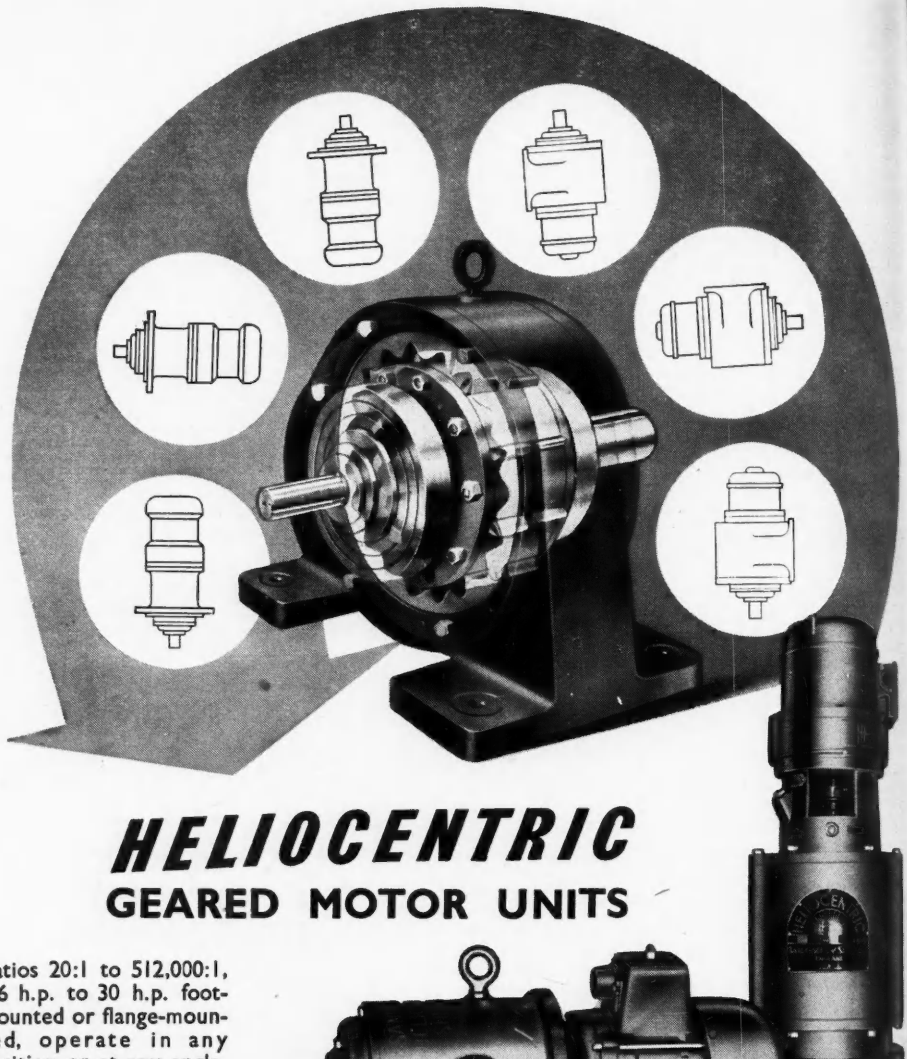

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Film Unit, begins by recalling the life and work of Sir Joseph Whitworth, one of the founders of the organization, and shows, in a series of well-conceived and blended shots, examples of his machine tools and inventions, now preserved in the South Kensington Science Museum.

The greater part of this 35-minute production, however, concerns the essentially modern techniques employed by the company in the manufacture of their engineers' cutting tools, ranging from twist drills, taps, hobs, and milling cutters to files and hacksaw blades. All stages of manufacture are covered, from the electric-arc and high-frequency furnace production of tool steel to the multifarious operations required to produce the finished article, including inspection methods and the application of flow-production methods, where practicable.

As is only to be expected from a Film Unit of this calibre, this interesting film is well produced, though there is a tendency towards abruptness in some of the shots relating to manufacturing processes, probably because the production attempts to cover too much, with too little time in which to do it. In nearly all other respects, however, this new film is a worthy successor to, and embraces the qualities of, its outstanding predecessor, "Engineers in Steel" (reviewed in our issue of October, 1954), particularly insofar as its superb photography is concerned.

It is understood that arrangements are being made for similar screenings of this film to be held later this year at Newcastle, Manchester, Glasgow, Coventry, and Birmingham.

## NEW ENGINEERING WORKSHOPS FOR BRITISH OXYGEN

A large extension for plant manufacture is now being built by the British Oxygen Engineering Company at Edmonton.

The new Plant Department workshops have become necessary as a result of the continuous increase in the sales of plant and equipment for use both in this country and overseas.

The new building will be completed by next January and will be occupied in April. A rapid construction programme has been made possible by the adoption of building and construction methods already standardised by the Company. The building has been designed by B.O.E.'s own staff of architects and civil engineers, who are also supervising its construction.

Completion of the new plant buildings will complete a programme started in 1954 to centralise the British Oxygen Company's engineering and plant manufacturing activities at Edmonton.

When the workshops are completed, it will be possible to relieve congestion in the existing Plant shops, which will then be used for the fabrication of small air separation units and will also provide a much-needed extension to the Compresor, Pump and Expansion Engine assembly shops.

In addition to the new plant buildings, an extension to the existing Evaporator Shop has already been completed. This shop is reserved for the manufacture and assembly of distribution and control equipment normally installed in the works of the Company's customers.

These new buildings will not only provide adequate space for quantity production of the British Oxygen Engineering Company's standard and established plant and equipment, but will also provide ample accommodation for their large programme for the development of equipment of new design and processes exploiting novel circuits.

## SPECIAL COMMITTEE ON AUTOMATION

In view of the widespread interest aroused by the Institution of Production Engineers' Margate Conference on "The Automatic Factory—What Does It Mean ?" and the many problems which inevitably arise with the introduction of automatic control, it was decided at a recent meeting of the Institution's Council to set up a special committee to investigate the full implications of automation. The Chairman of the Committee will be Mr. A. F. Kelley, B.Sc., A.M.I.Mech.E., M.I.Prod.E., A.M.I.C.E., director and general manager (Manufacturing), Aero Engines Division, of Rolls-Royce Ltd., Derby.

Other members of the Committee are Sir Leonard Lord, K.B.E., President of the Institution ; Mr. G. R. Pryor, chairman of Council ; Mr. H. G. Gregory, vice-chairman of Council ; Mr. E. W. Hancock, M.B.E., director and general manager, Humber Ltd. ; Sir Walter Puckey, immediate Past President of the Institution ; Mr. B. H. Dyson, general works manager, Hoover Ltd. ; The Earl of Halsbury, managing director, National Research Development Corporation ; Mr. M. Seaman, director and general manager, British Oxygen Engineering Ltd. ; Mr. R. Telford, general works manager, Marconi's Wireless Telegraph Co. Ltd. ; Mr. F. G. Woollard M.B.E.

The Committee will study the implications of automation in the broadest sense, and will pay particular attention to the effect of automation on the human being and on human relations in industry and in society.

## BUSINESS NOTES

**The Nevelin Electric Co. Ltd.** have moved to a newly acquired factory at Hurst Green, Oxted, Surrey. Tel. No. : Oxted 1450.

**A New Irish Oil Company** will be launched within the next few weeks. British Petroleum, Caltex, Esso, Regent and Shell are taking interest in the new company which will build a £10,000,000 refinery at Whitegate, Cork.

**The Cape Asbestos Co. Ltd.,** 114-116 Park Street, London, W.1, has formed a new company, Caposite Insulations Ltd. In association with Holmes Foundry Ltd., near Sarnia, Ontario, Canada, a factory is being built for the manufacture of amosite asbestos insulation materials. Cape Asbestos (Canada) Ltd., of which Mr. L. W. Dennis is managing director, will be the marketing organization.

**Metropolitan-Vickers Electrical Co. Ltd.** has from 1st September, 1955, transferred the Industrial Process Control Engineering Department to the recently formed Electronics Department. Mr. R. H. Kelsall, B.Sc., A.M.I.E.E., formerly assistant chief engineer, Industrial Process Control Department, becomes assistant chief engineer (Industrial Process Control), Electronics Department. This section is concerned with the industrial application of closed loop control systems in all its forms, including electronic and magnetic amplifiers ; the use of computers and associated techniques in conjunction with control systems will also be within its field.

**A Course on the Design of Welded Structures** is again to be held in Glasgow.

The Course will commence on the 10th January, 1956 at The Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow C.2, and the lectures will be held on Tuesday and Wednesday evenings from 7 p.m. to 8.30 p.m. over a period of seven weeks.

The Design Course is arranged to assist designers and draughtsmen of welded structures, and the lectures will be given by members of the Quasi-Arc Technical Staff. On the final evening the Guest Speaker will be Professor W. T. Marshall, of Glasgow University, who will be dealing with the Plastic Design Theory.

Further details along with the enrolment form can be obtained on application to the Constructional Design Department, Quasi-Arc Limited, Bilston, Staffs.

**Monsanto Chemicals Ltd.,** 8 Waterloo Place, London, S.W.1, have appointed Hygrotherm Engineering Ltd., 37 Upper Brook Street, London, W.1, sole selling agents in the United Kingdom for their organic silicate range of heat transfer fluids.

**British Driver-Harris Co. Ltd.,** Manchester 15, have established a Bi-metal Section to deal with all aspects of research, production and marketing. Thermostatic bi-metal can now be supplied in all standard types for a wide range of industrial and domestic applications.


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Our catalogue has details of all our equipment - stabilised power units, load cells and load rings, strain gauge and displacement transducer monitoring equipment, six-channel film recorders, counters, timers etc., and automatic manometers. Oh, yes! and we make a very good line in instrument cases too. Drop us a line; we are sure we can help you.

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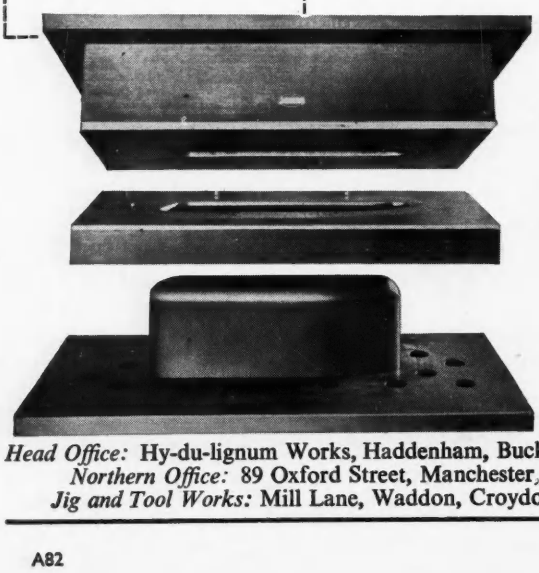
Illustration shows Hy-du-lignum Raising Tool for mild steel petrol tank pressings.

*Photograph by courtesy of Weathershields Ltd.*



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**The Automatic Coil Winder & Electrical Equipment Co. Ltd.,** 92-96 Vauxhall Bridge Road, London, S.W.1, have been entrusted with the sales of laminating, wire stripping and coil winding equipment, manufactured by Blume & Redecker, of Hanover, Germany, in the United Kingdom, the Commonwealth countries, China, Japan, Argentina, Russia and Eastern European countries. The English company will continue marketing of the "Douglas" and "Macadie" range of coil winders of their own manufacture.

**Ferranti Ltd.** have opened a new research and development establishment of their Aircraft Equipment Department at "Westwick," Bagshot Road, Bracknell, Berks. The primary concern of the department will be to develop new systems and components for aircraft electrical equipment and instrumentation, with particular reference to gyroscopic and associated navigation systems. Mr. W. A. Mallinson is chief engineer, and Mr. J. W. Barnes is chief research engineer of the establishment.

**Griffin & George Ltd.** announce that all London and Southern counties business is conducted now from their recently extended offices and warehouse at Ealing Road, Alperton, Wembley, Middx. Tel. No.: PERivale 3344.

**The Radio Industry Council** announces that the 23rd annual National Radio and Television Exhibition ("the Radio Show") will be held at Earls Court, London, from August 22 to September 1, 1956, with a pre-view for overseas and other special guests on August 21.

The Radio and Electronic Component Manufacturers' Federation announces that its annual private exhibition will be at Grosvenor House, London, W.1, from April 10 to 12, with—for the first time—a pre-view for overseas and other specially invited guests on the afternoon of April 9. Application for admission has to be made in advance to the Radio and Electronic Component Manufacturers' Federation, 21 Tothill Street, London, S.W.1.

**Consolidated Vacuum Corporation,** wholly owned subsidiary of Consolidated Engineering Corporation, 300 North Sierra Madre Villa, Pasadena 13, California, has been merged with the parent organization and will be known as the ConVac Division of Consolidated. Mr. Frank M. Jenner, Jr., will continue in charge of the Rochester, New York, operation as general manager of the ConVac Division.

**James Gordon & Co. Ltd.** have amalgamated with Hall Telephone Accessories Ltd., Dudden Hill Lane, London, N.W.10, who have formed at the same time a subsidiary company, Panellit Ltd., for the exploitation of an exclusive licence of the American Panellit, Inc.

**Head Wrightson Processes Ltd.,** 24-26 Baltic Street, London, E.C.1, have signed an agreement with D. Bonaldi & Co. for the manufacture in Italy of the Head Wrightson air-cooled heat exchangers.

**Elcontrol Ltd.** have taken a newly built factory, adjoining their premises at Hitchin, to provide three times the present floor area for much needed development.

**Stanley Howard Ltd.** have transferred their offices to 73 Devon Street, Saltley, Birmingham 7. The new telephone number is ASTon Cross 1275.

**Wickman Ltd.,** Banner Lane, Tile Hill, Coventry, have established a new area office at 36 Market Street, Nottingham (Tel. No. 43850), which will ensure a better and more widespread service in the highly industrialised North and East Midlands. The new area office will be under the control of Mr. E. J. Swinn. Mr. George Archibald has been appointed acting area manager of Wickman Ltd. for the Glasgow area, in succession to Mr. J. Macgregor.

**Gibbons Brothers Ltd.,** Dibdale, Dudley, Worcestershire, have acquired the licence to manufacture and sell "Thermo" Mill Furnaces which have been developed by Thermo Industrieofenbau G.m.b.H., a subsidiary company of "Ofu" Ofenbau-Union G.m.b.h., Düsseldorf. The salient aim in developing the "Thermo" furnace for medium and large outputs was to produce the ideal thermal treatment for steels prior to rolling, whatever their constitution, and, by providing positive zoning, the temperature and furnace atmosphere in each zone are capable of the precise control required for the purpose.

Refractory skids of a high degree and durability form a very important part of the design, as does the instrumentation necessary for accurate control.

**Aluminium and aluminium alloy ingots and castings for general engineering purposes. (B.S. 1490 : 1955)**

The British Standards Institution announces the publication of a revision of the above standard, which was first issued in 1949.

The revision introduces four new alloys. Alloys L.M. 17 and L.M. 19, which were included in the original edition, have been omitted.

Some of the alloys have been included in conditions not previously covered. And a number of amendments have been made to the chemical compositions and mechanical properties of the other alloys.

Copies of this standard may be obtained from the British Standards Institution, 2 Park Street, London W.1. Price 10/- each.

**BTH Turbine Manufacture.** In recent weeks the plan for re-equipping and expanding the British Thomson-Houston Company's existing turbine factory at Rugby has been somewhat overshadowed by the publicity given to the new BTH turbine factory now under construction at Larne in Northern Ireland. Some details of the scheme being put in hand at Rugby are now released.

It should first be mentioned that new buildings of increased manufacturing capacity were necessary because of the greater weights and dimensions of the increased size of turbo-alternators of the latest design, and the factories now being erected at Larne are for these large units—30 MW and above. In parallel with this, the capacity at Rugby is being expanded by re-layout of the buildings and the continuation of the replacement programme on machine tools and equipment.

During the period of transition the Rugby Works will continue to manufacture all types of turbine plant, but as the Larne Factory becomes available for the production of the larger units Rugby will concentrate on those sizes for which its plant and equipment are eminently suitable.

The Rugby Factory has a full order book, and when the plan is complete a substantial increase in the present labour force will be required. This plan, which will take approximately four years to complete, will provide the latest and most efficient machine tools and equipment, and a layout designed on sound principles of efficient material handling and processing.

A large proportion of this new plant is now on order, and some of the new machine tools have already been delivered.

When completed the BTH Turbine Factory at Rugby will be one of the best equipped in the country, and with the increased capacity available will be in a position to manufacture in increasing quantities under efficient conditions the smaller types of turbo-alternators, marine turbines, gas turbines, large industrial gear boxes, compressors, and blowers.

**The Power-Gas Corporation Ltd.,** Stockton-on-Tees, have been appointed by Imperial Chemical Industries Ltd., Billingham Division, to act as main contractors in connection with a substantial extension of their ammonia synthesis gas plant.

The plant, which will be built under the overall technical direction of I.C.I., is a new departure in this country. I.C.I. themselves are designing the oil gasification units in accordance with information supplied by the Texaco Development Corporation. Oil will be gasified with oxygen under pressure, and the equipment to be provided will also include oxygen plant, carbon monoxide conversion plant, gas purification plant and compressors.

As part of the purification train The Power-Gas Corporation Ltd. are designing and supplying a plant for the removal of carbon dioxide and hydrogen sulphide by means of hot potassium carbonate solution.

**Davey, Paxman & Co. Ltd.,** of Colchester, announce that they have concluded an agreement with the Breda Motori S.p.A., of Milan, Italy, under which the Breda Motori Company will manufacture and sell in Italy the Paxman type YL engine (9¾" × 10½" stroke).

The YL engine is manufactured in 8, 12 and 16-cylinder engines, having a power range of 432-2332 bhp at speeds from 500 to 1,000 rpm in its several forms. It is suitable for marine, industrial and traction application, and recent installations in this country and in Canada, Sierra Leone, Sudan and India include units for factory power supply, a.c. current generation, and propulsion units for ice-breakers, floating cranes, diesel electric trawlers and dredgers.

## CONTRACTS

The New Zealand Government has awarded a contract to **The English Electric Co. Ltd.** to supply three 30,000 kW steam turbo-alternator sets for a new power station to be built at Huntley in the Auckland area of the North Island, New Zealand. The approximate value of the contract is over £800,000.

Huntley Power Station will be the first major steam station in the North Island, where the full development of the hydro-electric resources has necessitated the installation of a steam station to provide extra power. The station will have a total installed capacity of 180,000 kW.

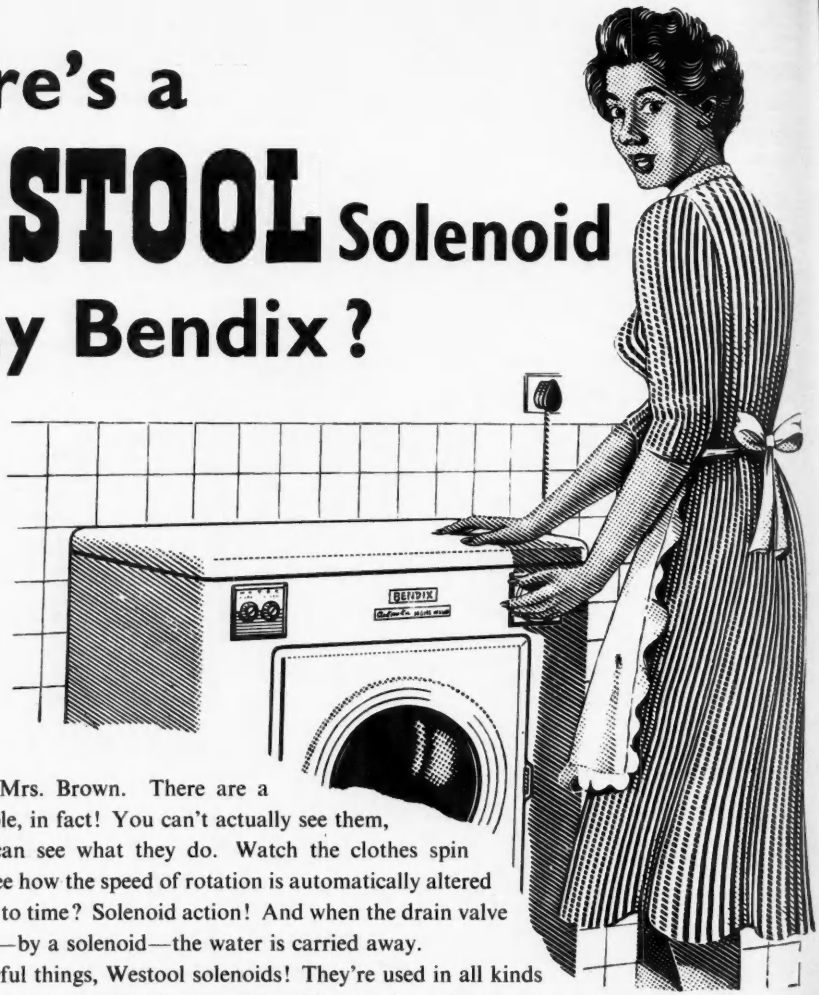
The sets will be built at the English Electric Company's works at Rugby and Stafford. They will be similar to those already supplied by English Electric to the Central Electricity Authority in Britain and to others being built for Vierfontein Power Station, South Africa, and Salmossari Power Station, Finland.

**The Power-Gas Corporation Ltd.,** Stockton-on-Tees, has received an order from Unilever Limited for the production of high purity hydrogen from propane, using the Hercules reforming process.

The plant, which will be capable of producing between 16,000 and 22,000 cubic feet of hydrogen per hour, will consist of a reforming furnace, followed by two stages of CO conversion and $CO_2$ removal and methanation and, in addition, hydrogen compressors, propane and high pressure hydrogen storage equipment and a Wiggins gasholder of 7,500 cu. ft. capacity. The hydrogen will be used for hardening edible oils at the Purfleet Works of Van den Berghs & Jurgens Limited.

**Enfield Cables Ltd.,** Brimsdown, Middlesex, announce that they have been awarded a contract to the value of approximately $500,000 by the Hydro-Electric Power Commission of Ontario, Canada. The cables will be laid in Ottawa, and they will cross the well-known Rideau Canal in the capital city.

# There's a **WESTOOL** Solenoid in my Bendix?




YES, Mrs. Brown. There are a couple, in fact! You can't actually see them, but you can see what they do. Watch the clothes spin round—see how the speed of rotation is automatically altered from time to time? Solenoid action! And when the drain valve is opened—by a solenoid—the water is carried away.

Wonderful things, Westool solenoids! They're used in all kinds of equipment to do all kinds of jobs. They push and pull, open and shut, stop and start—no wonder more and more manufacturers are realising that solenoid action can be the means of increasing the efficiency of their machines.

*Get in touch with Westool for full information and advice on solenoid applications.*

The Bendix Washing Machine, manufactured by Fisher & Ludlow Limited, incorporates Westool Solenoids Series 400 and 500.

WESTOOL LIMITED

**ST. HELEN'S AUCKLAND, CO. DURHAM**

*Telephone: West Auckland 317 (4 lines)* *Cables: Solenoid, West Auckland*

***Export Enquiries to Export Managers*: Stamm & Partners Ltd., 59 St. Martin's Lane London, W.C.2**

Telephone: Temple Bar 5383 (10 lines) Cables: Stamstam, London

*Westool also make Coils, Coil Winding Machines, Transformers, Warner Brakes & Clutches, Grinders, Small Motors, Vibrators, Air Conditioners, etc.*

Tibl7

2¼ miles of 115 kV., double circuit, 80 mVA. Pipeline Compression Cables (conductor size 300 mcm.) are to be laid by Enfield Cables' Contract Department in Canada. The installation is due to be commissioned on May 1st, 1956.

**The Power-Gas Corporation Ltd.** have received an order from Laporte Chemicals Ltd. for a Hercules reforming plant to produce high purity hydrogen. The plant will consist of a reforming furnace followed by 3 stages of CO conversion and $CO_2$ removal with methanation and a Wiggins gasholder.

**The General Electric Co. Ltd.** has received an order, to the value of approximately £93,000, for a fully-automatic, Ward Leonard control, 4-rope friction winder to be installed at Seafield Colliery, East Fife Area, National Coal Board.

The winder will serve the No. 1 shaft at this colliery and is designed to raise a coal load of 15 tons per wind in skips, from a depth of 1,930 ft. This will give an output of 615 tons per hour R.O.M. coal. The 10 ft. diameter friction drum will have a speed of 59·45 rpm and carry four 1¼ in. diameter locked coil ropes.

Twin D.C. motors of 1350 hp, to be built at the Company's Witton Works, will drive the drum through single-reduction gearing. They will be supplied from a Ward Leonard set driven by a 2300-hp synchronous induction motor. The G.E.C. system of closed loop speed control will be used, operating through high-response control exciters providing overriding torque limitation.

**The British Thomson-Houston Company,** Rugby, have received, through their associated company, Australian Electrical Industries Pty. Ltd., an order worth approximately £400,000 for the Broken Hill Proprietary Co. Ltd., Australia. This covers the electrical driving equipment for an 18" continuous steel strip and skelp rolling mill to be installed at the Broken Hill Proprietary Co.'s Newcastle Works, New South Wales. The BTH plant includes fourteen D.C. motors totalling 9800 hp, two 3500 kW banks of grid-controlled mercury arc rectifiers for supplying electric power to the motors, together with control gear.

**The G.E.C. Telephone Works** in Coventry have recently concluded negotiations with the Telephone Organisation of Thailand for the supply and installation of automatic telephone equipment in the capital city of Bangkok to a value of £300,000.

International competition was particularly intense, tenders having been received from many foreign countries.

# Classified Advertisements

*The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.*

## MACHINERY FOR SALE

**150 tons × 120 in.** NEW HYDRAULIC PRESS BRAKE by Brauchli. Immediate delivery. Built-in Motorised pump. Between uprights 104 in. Length of bed 120 in. Stroke 3½ in. Weight about 6½ tons. Steel plate construction. **F. J. Edwards Ltd., 359 Euston Road, N.W.1.**

**TWO DOUBLE ACTION HYDRAULIC PRESSES FOR SALE. BRITISH CLEARING DH 55-35-30.** Pressure punch 55 tons, blankholder 35 tons, both rams 90 tons. Steel frame. Both strokes adjustable, punch up to 8 in., blankholder up to 4 in. Between uprights 32 in.

**ONE DOUBLE ACTION HYDRAULIC PRESS FOR SALE. BRITISH CLEARING DH 80-55-36.** Pressure punch 80 tons, blankholder 55, both rams 135 tons. Both strokes adjustable, punch up to 20 in., blankholder up to 10 in. Between uprights 38 in.

Each complete with cushioned bed, all self-contained hydraulic equipment for motor drive 400-440/3/50. Photographs of each machine available and full details from :—

**F. J. EDWARDS LTD.,**
**359, Euston Road, London, N.W.1.** EUSton 4681
or
**41, Water Street, Birmingham, 3** CENtral 7606

**THE CORRY PLATFORM TRUCK** is the lowest priced truck available at the present time with a one ton load capacity. Fitted with roller bearing wheels and rubber tyres. Details from **J. L. Allen & Co., Chedington, Beaminster, Dorset.**

## SITUATIONS VACANT

**DESIGNER OF MAGNETIC RECORDING EQUIPMENT** required for the Domestic Electronics Division of E.M.I. Ltd. A number of interesting projects are in hand giving scope for inventive ability to applicants who have knowledge of electrical circuitry and who are interested in small mechanisms. The vacancy is in the Laboratory at Greenford, and salary will be commensurate with ability. Write in the first instance, giving fullest details of education and experience, to **Personnel Department/CLR, E.M.I. Ltd., Hayes, Middlesex.**

The Wolverhampton branch of a world-wide industrial organisation offers permanent positions with excellent prospects of promotion for both senior and junior staff as **TECHNICIANS** and **DESIGN AND DETAIL DRAUGHTSMEN** on interesting design and development work in connection with atomic energy, aircraft, guided weapons and industrial engineering projects.

**TECHNICIANS :** Engineering or Mathematics degree preferred—minimum acceptable qualification Higher National Certificate, engineering standard; for junior positions in this category engineering experience is not essential.

**DESIGN AND DETAIL DRAUGHTSMEN :** Higher National Certificate in engineering preferred—this may be waived for designers with worthwhile experience in mechanical engineering; for junior positions in this category applicants studying for Ordinary National Certificate/Higher National Certificate in mechanical engineering will be considered.

Dependent upon suitable experience and qualifications, salary scales range to approximately £1,250 per annum for Technicians, £900 for Design Draughtsmen, and £750 for Detail Draughtsmen. Candidates possessing a particularly high potentiality will be eligible for higher salary levels than those quoted.

Company employee schemes and excellent working conditions generally include superannuation scheme, a profit-sharing scheme, a 5-day 40-hour week and good Canteen and Sports Club facilities. Travel and other incidental expenses will be defrayed by the Company for selected candidates called for interview.

Replies should be addressed to Box No. 41.

**IMPERIAL CHEMICAL INDUSTRIES LIMITED**
METALS DIVISION,

one of the largest producers of non-ferrous metals and the principal producer of Titanium in the United Kingdom, has vacant a number of interesting and responsible posts carrying attractive financial and other prospects. These vacancies are for technical personnel in the Research, Engineering and Production Departments, and are mainly in the Midlands although there are others of particular interest to Metallurgists and Mechanical Engineers at Liverpool.

Applications are invited for :

**TECHNICAL OFFICERS :** Candidates should be honours graduates, or equivalent, in Metallurgy, Physics and Mechanical or Electrical Engineering.

**ASSISTANT TECHNICAL OFFICERS :** This description includes other scientific staff who possess technical knowledge and/or experience in the fields of Metallurgy, Chemistry, Physics and Engineering.

**LABORATORY ASSISTANTS :** Young men and women between the ages of 16 and 22 interested in either Metallurgy, Chemistry or Physics, with the minimum qualification of a good General Certificate of Education at Ordinary Level are required. Facilities for further education are available.

All these posts are permanent and employees over the age of 20 join the Pension Scheme and qualify after two years' service for inclusion in the Company's Profit Sharing Scheme. Excellent Canteen facilities are available. Consideration will be given to assisting with removal expenses of married men. Out of pocket expenses are paid to applicants invited for interview.

Application forms may be obtained from **Staff Manager, I.C.I. Metals Division, Kynoch Works, Witton, Birmingham 6,** quoting reference GEN/2.

**PLANNING ENGINEERS**

**FERRANTI LIMITED, Edinburgh,** are anxious to recruit men who have experience of detailed planning. They should have completed an apprenticeship in engineering, and should preferably hold a Higher National Certificate. They will be employed on the production of precision instruments under modern production methods. There is wide scope for those with initiative and commensurate salaries will be paid. Please apply, giving full particulars of career to date, and quoting Ref. P.E./85 to the **Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh, 5.**

## BEARINGS

**BALL & ROLLER BEARINGS.**—All types and Sizes, Largest Stocks, Lowest Prices. Same day dispatch. **895-921 Fulham Rd., London, S.W.6.** Renown 6174 (Ext. 24).

## BOOKS RECEIVED

**An Introduction to Fluvial Hydraulics.** By Serge Leliavsky, Ph.D., M.I.C.E., M.Am.Soc.C.E. 270 pp., 88 illustrations. Publishers: Constable & Company Ltd., 10 & 12 Orange Street, London, W.C.2. Price :—30/-.

In this book, Dr. Leliavsky, who was formerly Director, Designing Service, Reservoirs and Nile Barrages Department, and Chief of the Designing Office, Irrigation Projects Departments, Ministry of Public Works, Cairo, has compiled a short, but none the less comprehensive, survey of the various theories, methods, and facts relating to the flow of water in erodible channels, which are themselves the natural creations of this flow. The current which erodes such a channel is, in turn, controlled by the ever-changing shape of the channel it has eroded. As a result, there arises the problem of successive approximations, not only of interest to the research engineer but of great importance to the practical designer.

It is believed that no such comprehensive summary as that given in this interesting book has ever before been published in English.

**Theory of Machines.** By W. G. Green, B.Sc., Ph.D., M.I.Mech.E. 1056 pp., 609 illustrations. Publishers: Blackie and Son Ltd., 17 Stanhope Street, Glasgow, C.4. Price :—40/-.

This textbook is eminently suitable for students preparing for the External Degree Examinations of the University of London, College Associateship and Higher National Certificate Examinations, and examinations of the Professional Institutions. In this connection, it has been the author's experience that such students have generally lacked a knowledge of the fundamental approach to the study of the "Dynamics of a Particle and of a Rigid Body," and were thus deprived of one of the most important assets in the study of the theory of machines. As a result, the first two chapters in this book were prepared with this point in mind and may be regarded as mainly for reference purposes.

The author has successfully achieved his aim of preserving a logical sequence throughout, and this has largely dictated the size and content of the book. A large number of worked examples is included, mainly taken from University of London External Degree Examination papers and from those of the Professional Institutions. In addition, a substantial collection of problems, with solutions, is appended to each chapter.

**Brazing Manual.** Prepared by the Committee on Brazing and Soldering of the American Welding Society. 200 pp., 83 illustrations. Publishers: Reinhold Publishing Corporation, New York, and Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price :—38/-.

There has always existed some confusion in the use of the words *welding*, *brazing*, and *soldering*. To clarify this situation the American Welding Society has adopted the word *welding* as a generic term to cover the joining of metals by the application of heat. In this connection, this Manual confines its discussion solely to the brazing processes, which are defined as "a group of welding processes wherein coalescence is produced by heating to a suitable temperature above 800° F and by using a non-ferrous filler metal having a melting point below that of the base metals. The filler metal is distributed between the closely-fitted surfaces of the joint by capillary attraction."

This interesting volume contains the latest details of all brazing processes used in the automotive, aircraft, refrigeration, electronics, and other mass-production metal industries, and includes all the practical information, compiled by leading authorities, required to deal with every type of brazing problem. Chapters are devoted to describing the principles, equipment, and procedures involved in all eight brazing processes; to every operation, ranging from pre-cleaning and surface preparation to post-braze cleaning and inspection; and to the techniques of brazing aluminium, magnesium, copper, steels, iron, nickel, and many other metals. In addition, full details are given regarding joint design, base and filler metals, fluxes, and atmospheres; quality control, safety, and health protection; defects and their prevention; and metals in similar and dissimilar combinations, and filler metals used.

The book should prove of inestimable value to designers, metallurgists, engineers, and, indeed, to all concerned with the joining of non-ferrous metals or ferrous to non-ferrous metals.

## LATEST INDUSTRIAL LITERATURE

**1. Edge-Lighted Signs.** In a well-produced and illustrated 4-page pamphlet, details are given of a range of edge-lighted signs for a variety of purposes and of numerous types, including ceiling, bracket, wall, and counter models.

The body of the sign is made of brass, with a removable cover secured by two thumbscrews, to simplify re-lamping without tools, and complete with a 4½-in. diameter canopy for mounting to an outlet box. The sign is supplied wired for use with an 8-W fluorescent lamp, with approved ballast, sockets, and leads. Single-face signs are made of clear lucite or plexiglas panels, ¼ in. thick, attached securely to the cover; double-face signs use two ⅛-in. panels of clear lucite or plexiglas, with a black metal separator. All these signs are available in a number of finishes.

**2. Dissolved Oxygen Recorder.** Designed specifically to record the extremely low concentrations of dissolved oxygen in the water fed to modern steam turbo-electric sets, the entirely new electro-chemical type of dissolved oxygen recorder described in a 4-page, illustrated brochure employs an analysing unit which is based on an adaptation of polarographic principles, depending on the fact that a small potential applied between two suitable electrodes immersed in water which has been rendered conductive will produce a current whose value depends on the concentration of reducible substances in the water.

The equipment consists of four units, i.e., the cooler and flow-control valve, the analyser unit, the control panel, and the recorder. A simple, but accurate, sensitivity-checking device, operating on electro-chemical principles, has been built into the analyser, permitting rapid standardizing of the equipment, while in service, by unskilled personnel.

**3. Diesel Power Packs.** A series of leaflets describes and illustrates a range of 3·4 and 5·1-litre diesel power packs, designed as self-contained, compact, and sturdy units, and supplied complete with radiators of temperate or tropical capacity, fuel tanks, silencers, shaft extensions, and electric starting equipment.

Incorporating the latest design developments, these efficient power units are ideal for such applications as agricultural machinery, industrial plant, compressors, generating sets, excavators, crushing plant, earth-moving plant, road-rollers, concrete-mixers, mobile cranes, dredging plant, oil-drilling rigs, rail-cars, and pumps.

**4. Oxygen Cutting and Profiling Machines.** Built to machine-tool standards by a company which has specialized in oxygen cutting and profiling for over thirty years, the range of oxygen cutting and profiling machines described in a well-produced and illustrated 8-page brochure is constructed to give a very high degree of accuracy over the entire cutting area.

Without making any structural modifications, these machines can easily and quickly be converted into multi-burner equipment. Furthermore, the length can be increased in multiples of 5 and 10 ft merely by the addition of rail sections and their supports. Other interesting features include conveniently grouped and duplicated controls, so that the machine can be operated either from the tracer head or the burner end, and the fact that it is easily adapted to automatic profile welding.

**5. Metallic Gland Packings.** Suitable for all diesel engines, for air, gas, and ammonia compressors, and for reciprocating shaft applications, a range of metallic gland packings described in a 4-page, illustrated leaflet is stated to be cheaper than existing types and capable of installation without skilled hand fitting. Furthermore, once installed, the packing is entirely self-compensating, requiring no further adjustment.

The packing consists of a series of "L"-section cast-iron carrier rings. In the recess of each carrier ring are two sealing rings, side by side, each consisting of three segments, and around these sealing rings is an inwardly contracting spring ring. A number of these complete rings (usually from four to eight, depending on the application) comprises the complete packing.

**6. Magnetically Operated Valves for High-Vacuum Systems.** A range of magnetic valves, described in an illustrated 4-page brochure, incorporates all the features essential to good vacuum engineering, including solid machined bodies free from casting leakages, demountable vacuum unions, and sealing characteristics for high-vacuum isolation.

Features of these valves include a core and winding, designed to give maximum power, and an extremely useful simple air-admittance valve of $\frac{1}{16}$-in. bore. Furthermore, they can be used for vacuum and the control of any non-corrosive gas or vapour.

**7. Multi-Wash System for Dust-Laden Gases and Fumes.** In a very well-produced and illustrated 24-page booklet, details are given of a system intended to provide a complete solution for many problems involving the collection and cleaning of dust-laden air and other gases. While the collectors used form an integral and important unit of the system, other phases of the dust-removal problem have also been considered, including adequate ventilation at the dust source, transportation of the dust-laden gases to the collectors, and the subsequent removal of the dust from the collector effluent. Thus, each phase of the dust- or fume-handling problem has been solved by the correct application of a number of standard units, including collectors, ventilating hoods, settling tanks, pumps, and venting, each specifically designed for the particular duty involved and for operating in conjunction with each other.

With this system, maintenance requirements are brought to a minimum, as there are no moving parts in either the collector towers or in the remainder of the dirty-gas circuit. Furthermore, there are no nozzles to clog and no danger of blockage throughout the collector towers, while inflammable dust and/or carrier gases can be handled without risk of fire or explosion.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Company.....

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One example of Parker progress is the tractive type Speedslinger ramming machine illustrated above. It is the worlds latest type and one operator mounted jockey wise on the ramming head, can traverse and ram moulds situated anywhere within 20 ft. of his track, at the enourmous rate of 45 tons of sand per hour!

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**steel castings**

***Manganese, Carbon & Alloy Steel.***

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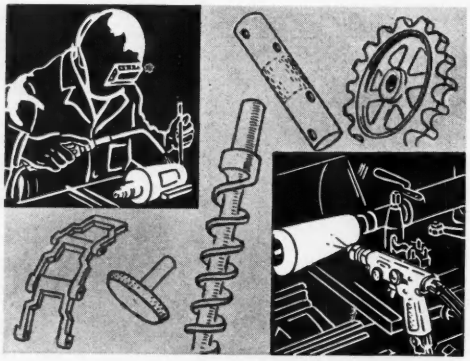
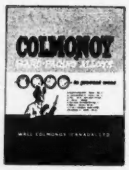


Write for this Colmonoy Hard-Facing Manual. It gives a complete hard-facing guide and a table on the properties of all Colmonoy Alloys.

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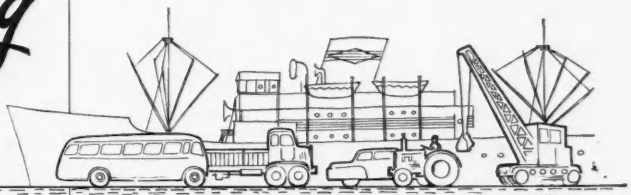

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*Technical publications on request.*

**SIGMUND PUMPS LTD**
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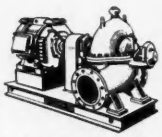
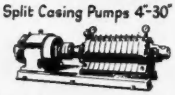
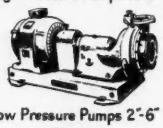
AGENTS IN ALL PARTS OF THE WORLD

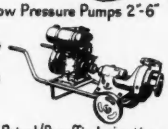

Split Casing Pumps 4"-30"


High Pressure Pumps 1½"-8"

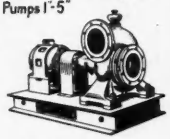
Diesel Pumping Sets 2½"-16"

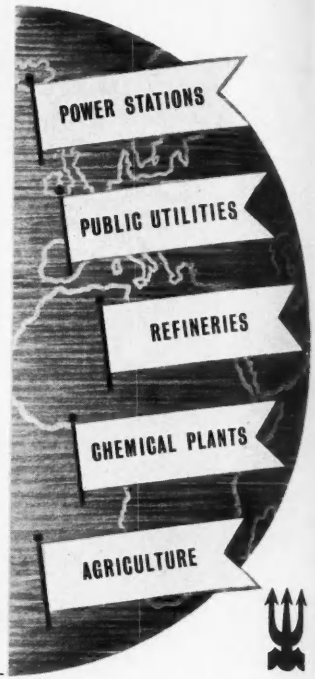

Low Pressure Pumps 2"-6"


Tractor Irrigation Pumps 4"-8"


Petrol/Paraffin Irrigation Pumps 1"-5"

Fast and loose Pulley Pumps 2"-16"


Low Head Pumps 8"-16"



# PRESSINGS

Ward (Metal Details) Ltd. specialise in the manufacture of all types of small and medium pressings. Illustrated here are but a few examples of the many shapes, sizes and thicknesses, in steel, tin plate, copper, etc. Complete assemblies can be fabricated from simple pressings by welding, soldering or brazing. Similar components can be produced from your designs and to your specification, and, if required, supplied in painted, plated or enamelled finishes.

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# NEW TWO-WAY RADIO EQUIPMENT

Demonstrations of a new equipment, designed in Cambridge, have been given in London recently to representatives of Police and Fire Services, Local Authorities and Industrial Organisations. This equipment has been designed to defeat the chronic shortage of two-way radio channels.

**Known as the Pye "Ranger", it is the solution to the frequency shortage which is ham-stringing mobile radio users in Great Britain!**

The new equipment operates on a channel spacing of only 25 Kc/s—a quarter of the customary spacing—thus potentially quadrupling the number of mobile radio channels. Robust construction, excellent performance and carefully selected components make it capable of operating under arduous conditions and in any weather.

This mobile radio is designed for fitting in the dashboard of ordinary cars and vehicles. The price of the equipment, notwithstanding its many-times improved specification, is approximately the same as that of earlier equipments which it now replaces.

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Trafalgar Guards are the product of true craftsmen weaving wire to any mesh from any metal and to any shape. 100 years of experience is your guarantee of quality, strength and fairness of price.

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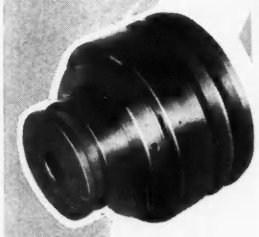
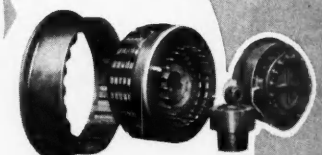


**CLUTCH-BRAKE ASSEMBLIES**

The illustration shows a pneumatic Clutch-Brake Assembly supplied for a 500 ton capacity forging machine.



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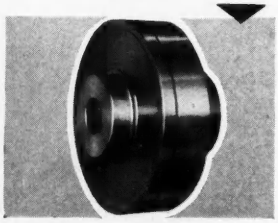

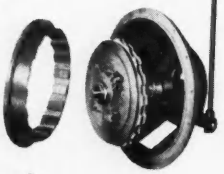

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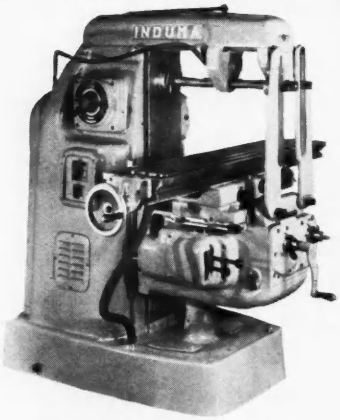


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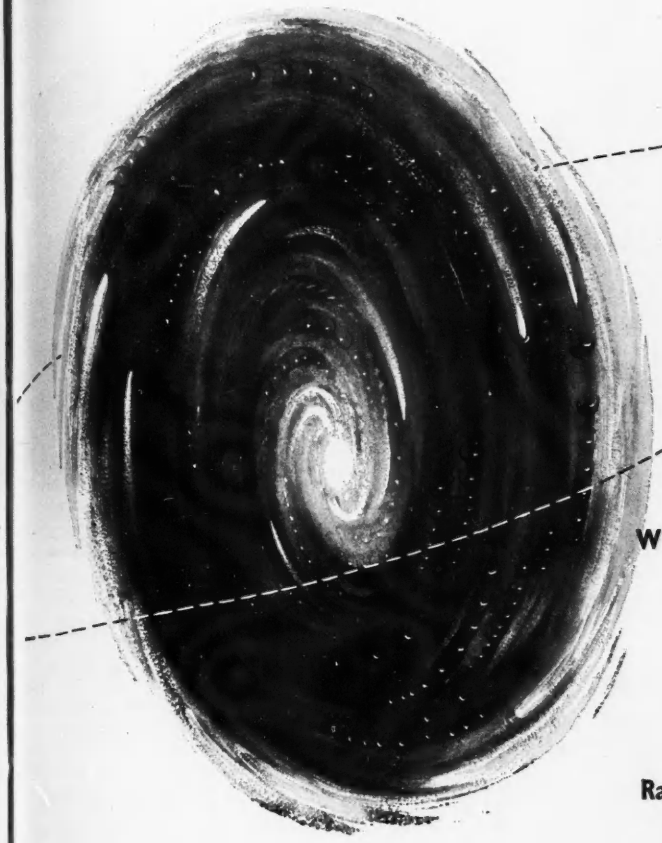

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BALL & ROLLER R&M BEARINGS

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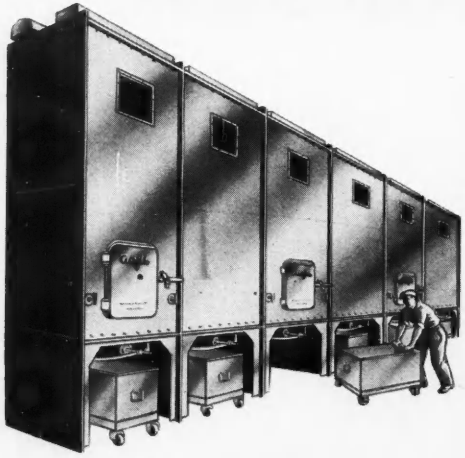

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For dealing with dry, non-fibrous, non-explosive dusts with air temperature not exceeding 160° F. Fully automatic shaking, mechanically controlled at specific intervals without interrupting production. This system does not involve rapping the fabric but uses the flow of air entirely for filter sleeve cleaning. Made on unit principle; can therefore be used in composite form according to requirements. Can be mounted on floor or steel supports at high level.

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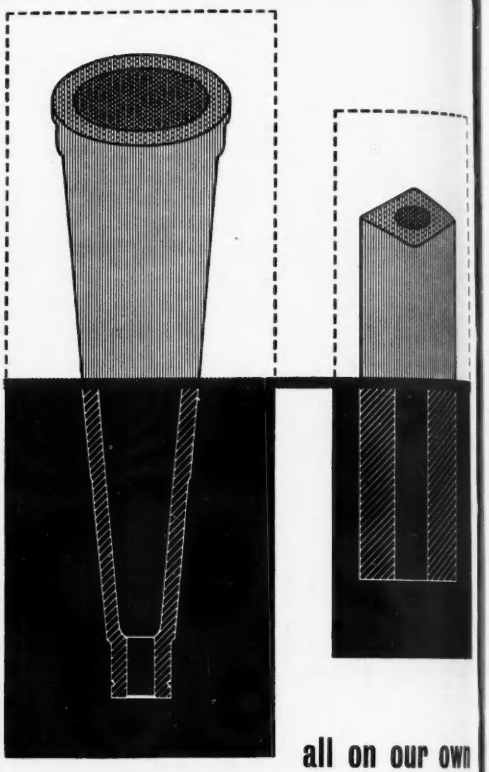

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We are the only people to commercialise *deep hole drilling*. By this method we produce hollow bored shafts, the chief advantages of which are as follows:—

**PRICES ARE KEEN** particularly where small quantities or special sizes are required, or where the bore diameter is less than half the outside diameter.

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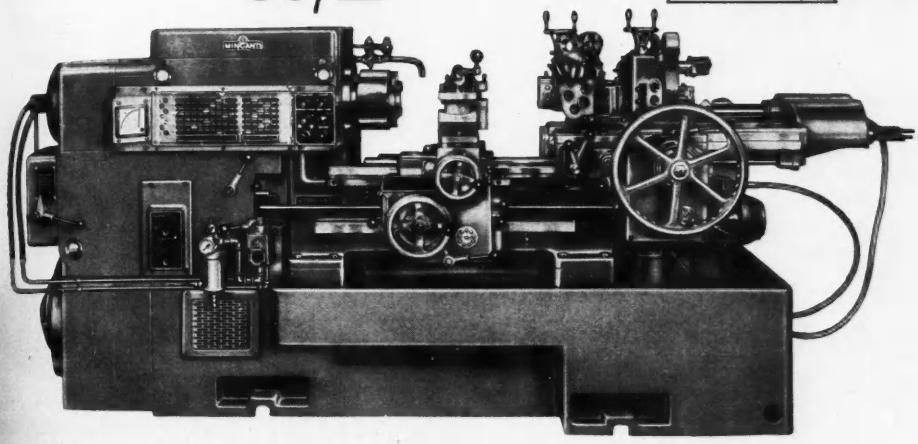

## GENERAL SPECIFICATIONS—

| | |
|---|---|
| Standardized spindle end | ASA 6″ |
| Dia. of hole in spindle | $2\frac{1}{4}$″ |
| Bar stock with collet, max. admitted | $2\frac{3}{16}$″ |
| Max. swing over bed ways | $17\frac{11}{16}$″ |
| Max. swing over carriage | $9\frac{1}{16}$″ |
| Number of spindle speeds | 8 |
| Spindle speed range, r.p.m. | 50-100-150-300-500-1000-1500-3000 |
| Hexagonal turret slide feeds— | |
| No. 4 High Range | .009″ to .061″ |
| No. 4 Low Range | .003″ to .02″ |
| Cross and Longitudinal feeds of the square turret slide— | |
| No. 7 High Range | .002″ to .112″ |
| No. 7 Low Range | .0008″ to .03″ |
| Dia. of hole on hexagonal turret | $1\frac{3}{4}$″ |
| Max. stroke of saddle (Hex. turret) | $8\frac{11}{16}$″ |
| Max. distance from spindle flange to hex. turret | $25\frac{3}{4}$″ |
| Max. power required | H.P.8 |
| Net weight with standard equipments | lbs. 6000 |

**The machine which "Thinks" for the Operator.**

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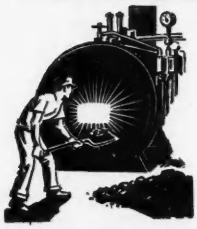
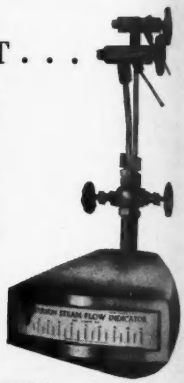


SAVE FUEL

FIT . . .

THE CURNON INDICATING STEAM METER



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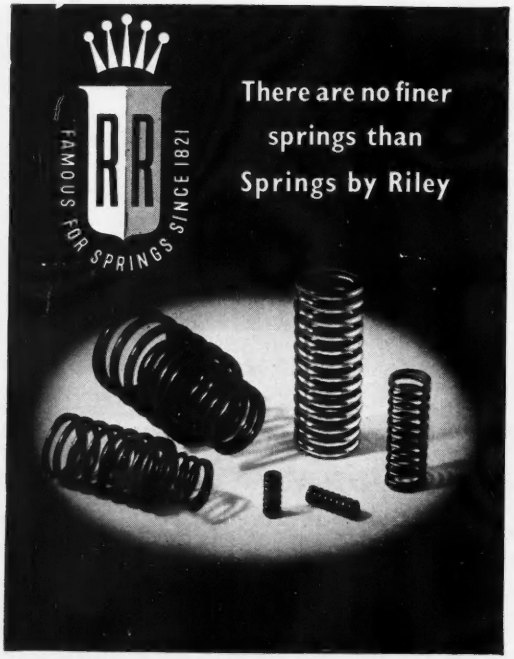
CLAUDE ROAD WORKS, CHORLTON, MANCHESTER, 21

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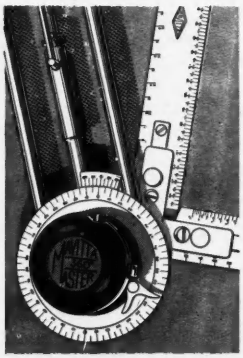

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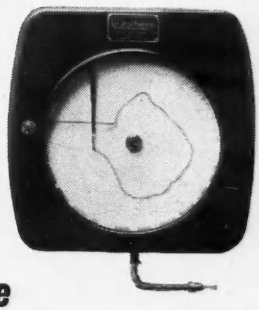

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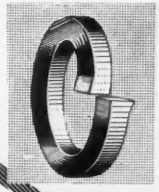

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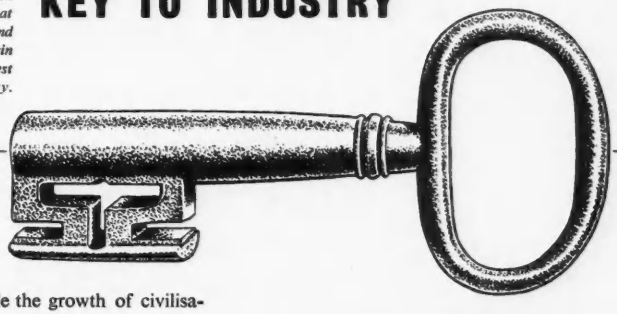

The development of steel made possible the growth of civilisation itself. For steel is the key to the good things of life as well as to the necessities; as essential to the maker of the precision watch as to the bridge-builder. Hallamshire high-grade Alloy and Carbon steels serve a multitude of industries in many ways.

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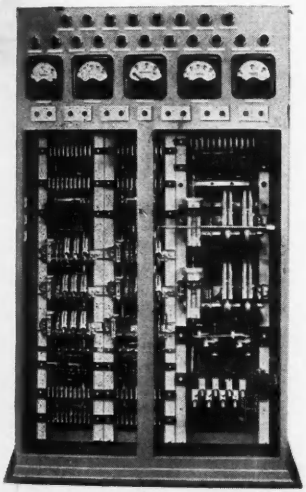

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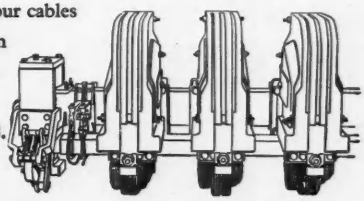

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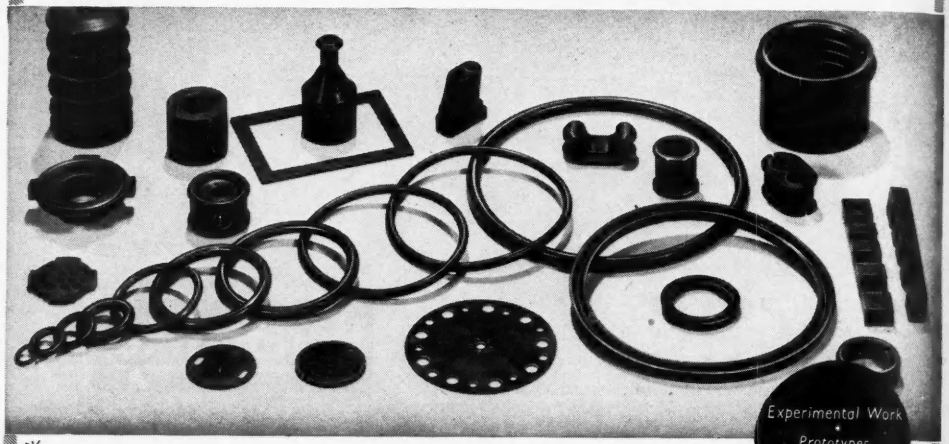

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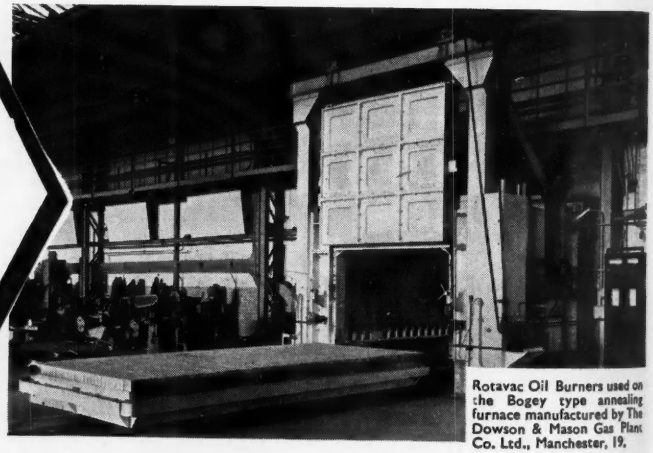

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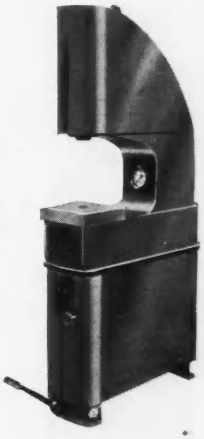

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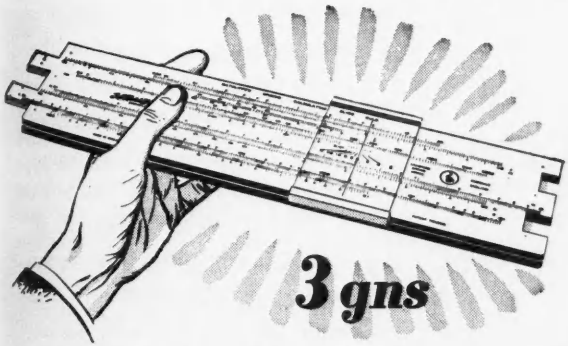


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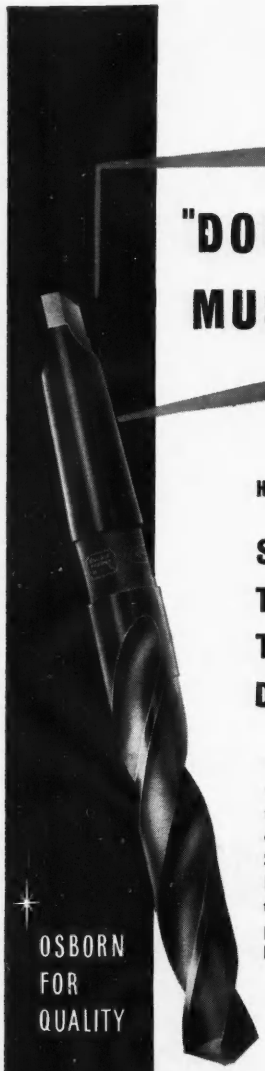

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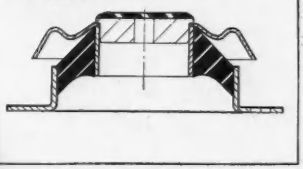

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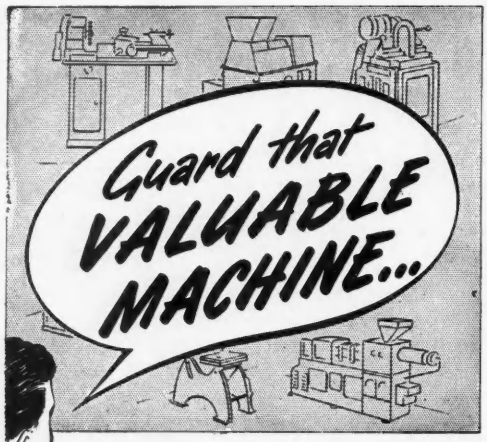


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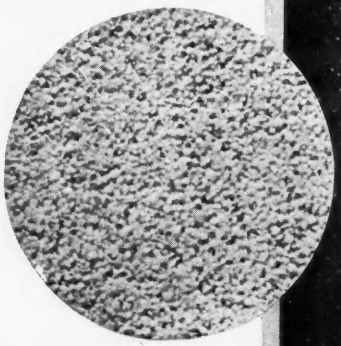

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ACID-PROOF POROUS CERAMICS

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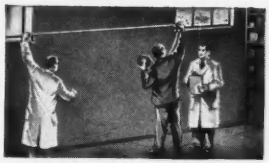

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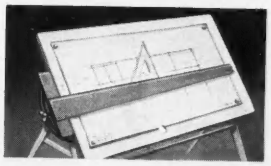
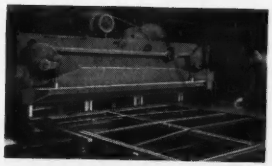
EVERTAUT will measure up space and will be pleased to advise and discuss any problems regarding steel storage equipment.



**PLANNING**

EVERTAUT engineers will plan your storage equipment to individual requirement from start to finish.



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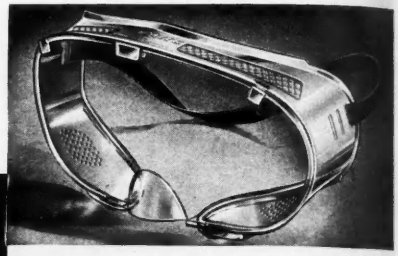

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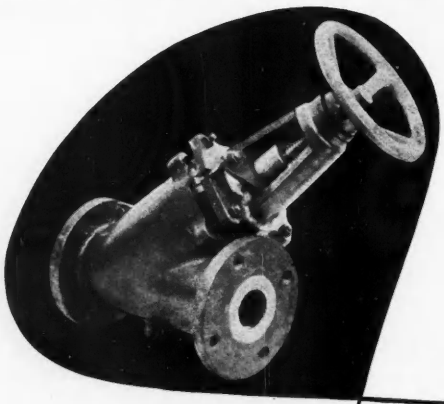

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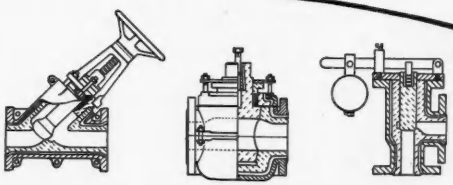

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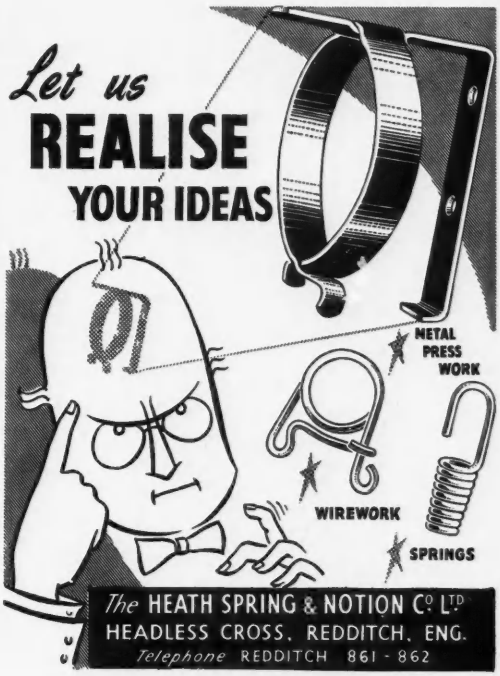


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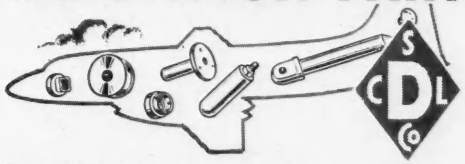


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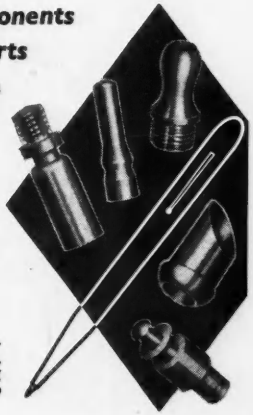

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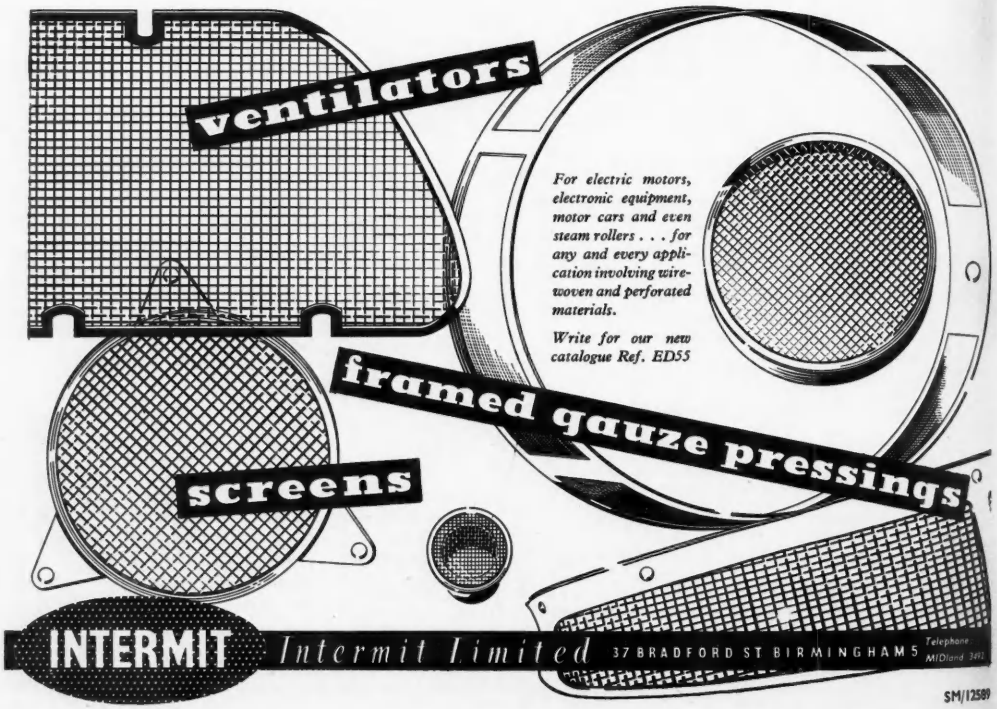
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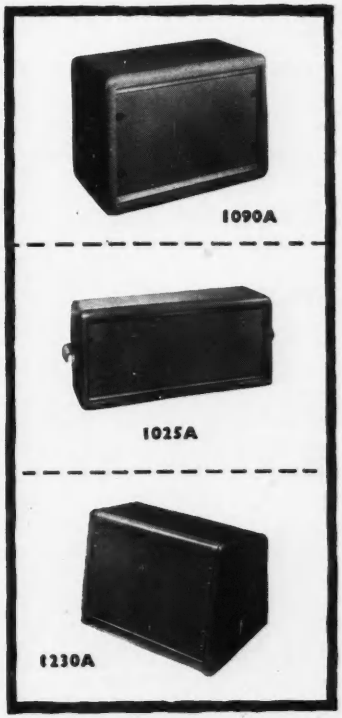


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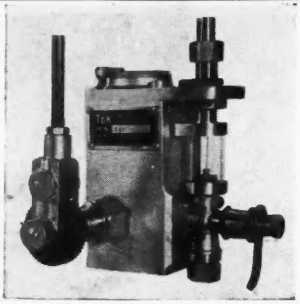

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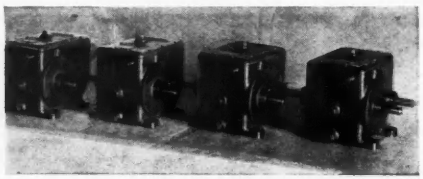

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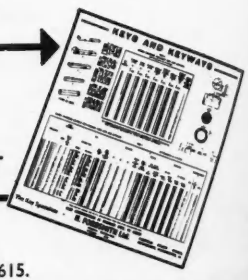


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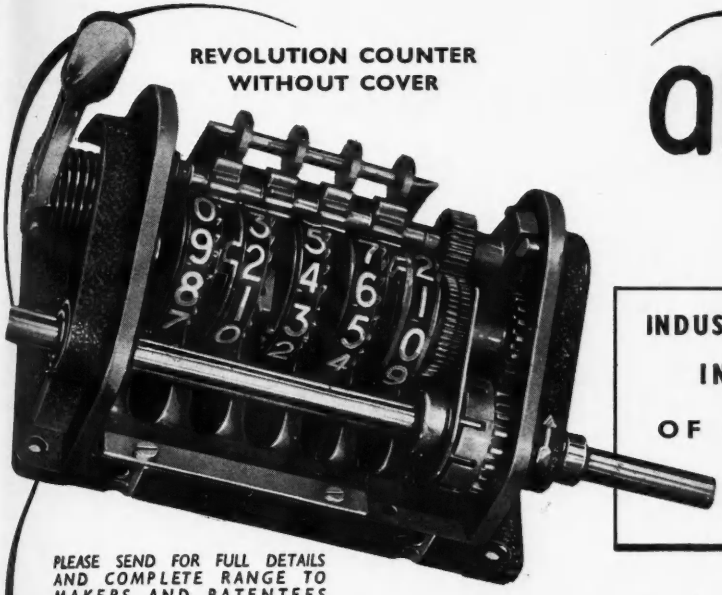


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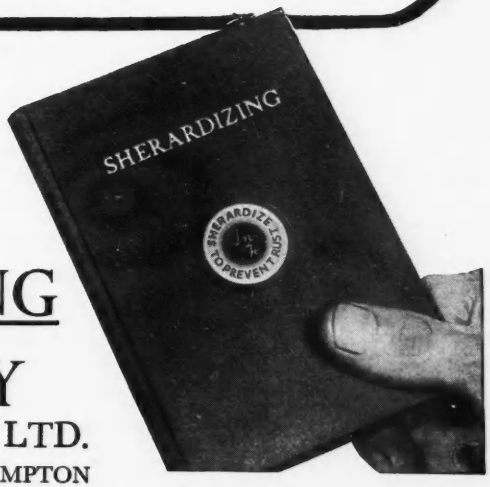


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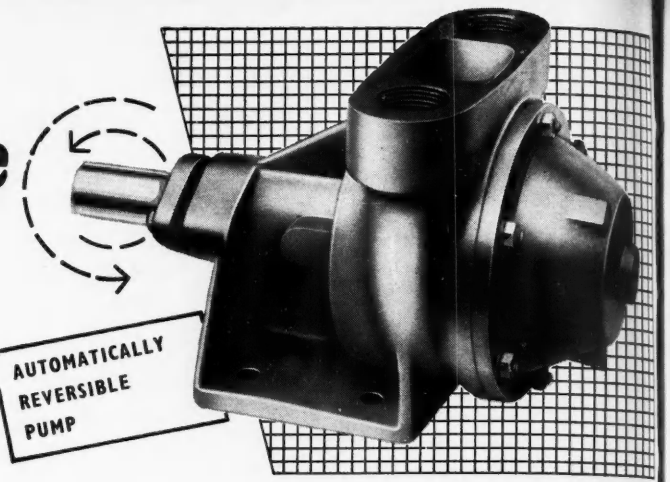


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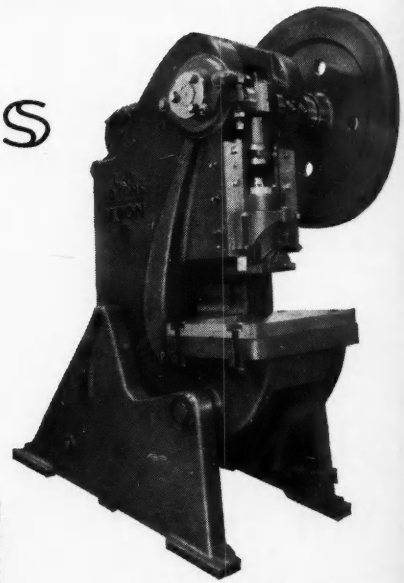

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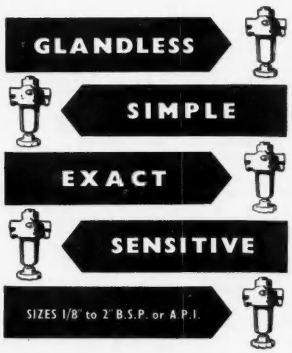


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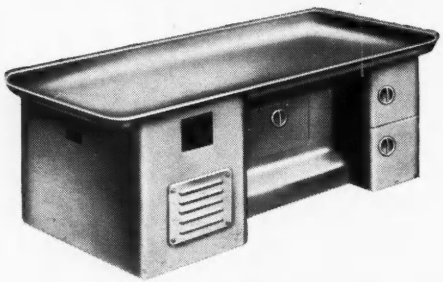

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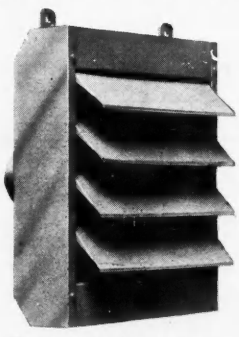

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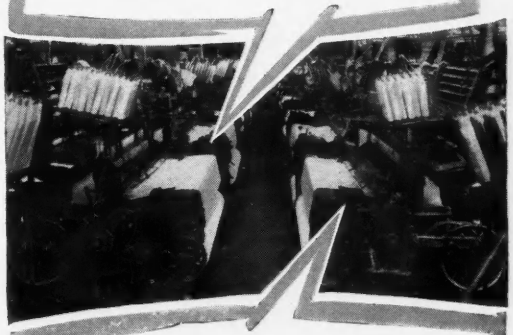

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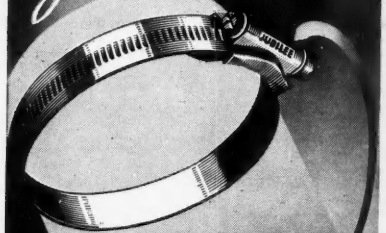

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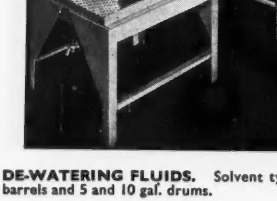

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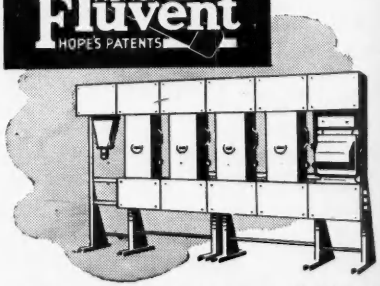

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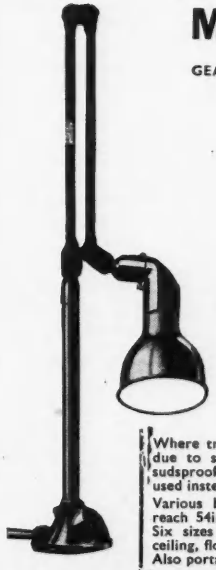

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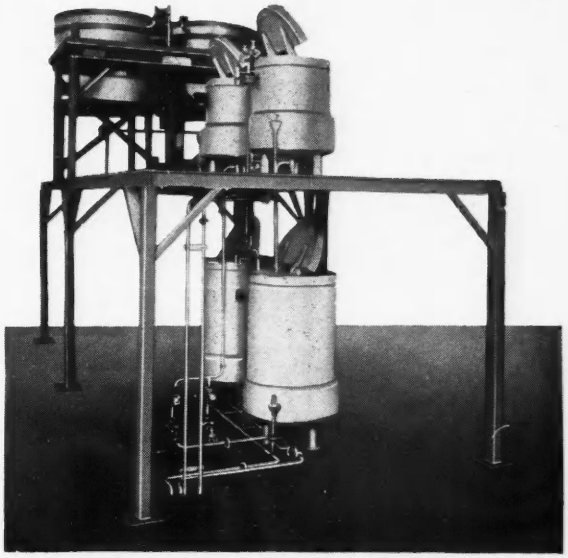

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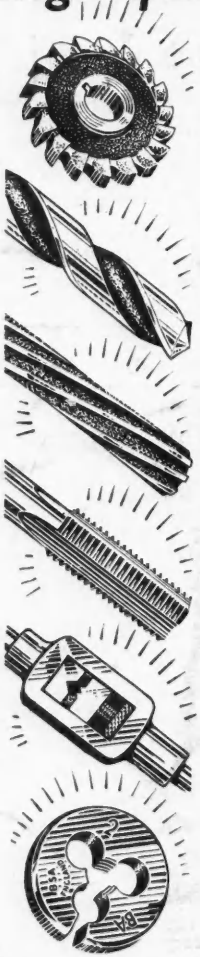

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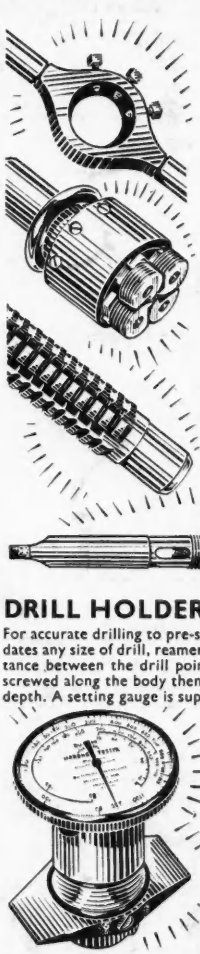

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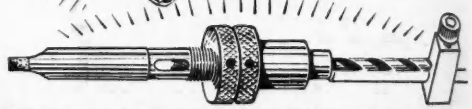

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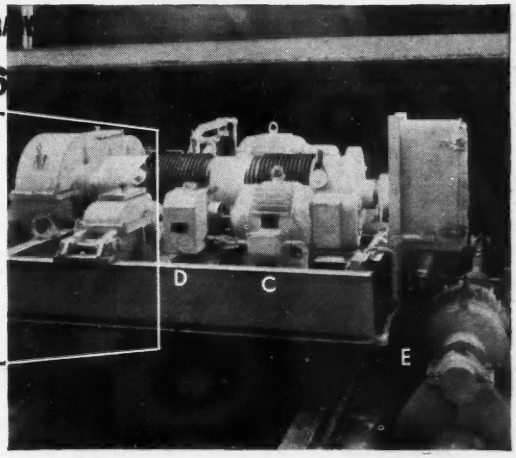
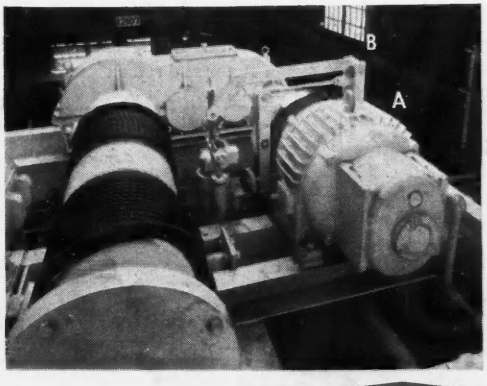



Metrovick equipment is well on top in this 10-ton Wharton overhead shop crane. The hoist is an 18-h.p. 720 r.p.m. M-V motor fitted with a thrustor-operated brake giving precise control with stable creeping speed on load. The need for inching is thus eliminated. Drives for the long travel and cross-traverse are M-V 10-h.p. 715 r.p.m. and 3-h.p. 700 r.p.m. type MZ slipring motors respectively. A 6-inch Perigrip brake operates on the cross traverse. Write for details of the range of M-V a.c. and d.c. motors, control gear and Perigrip electromagnetic brakes for crane drives.




*In the illustration (left) A is the 18-h.p. 720 r.p.m. hoist motor fitted with Stacreep thrustor control B. The long-travel drive, motor E, is shown at the top of page. The 3 h.p. cross traverse motor is seen at C and the 6-inch Perigrip brake at D.*

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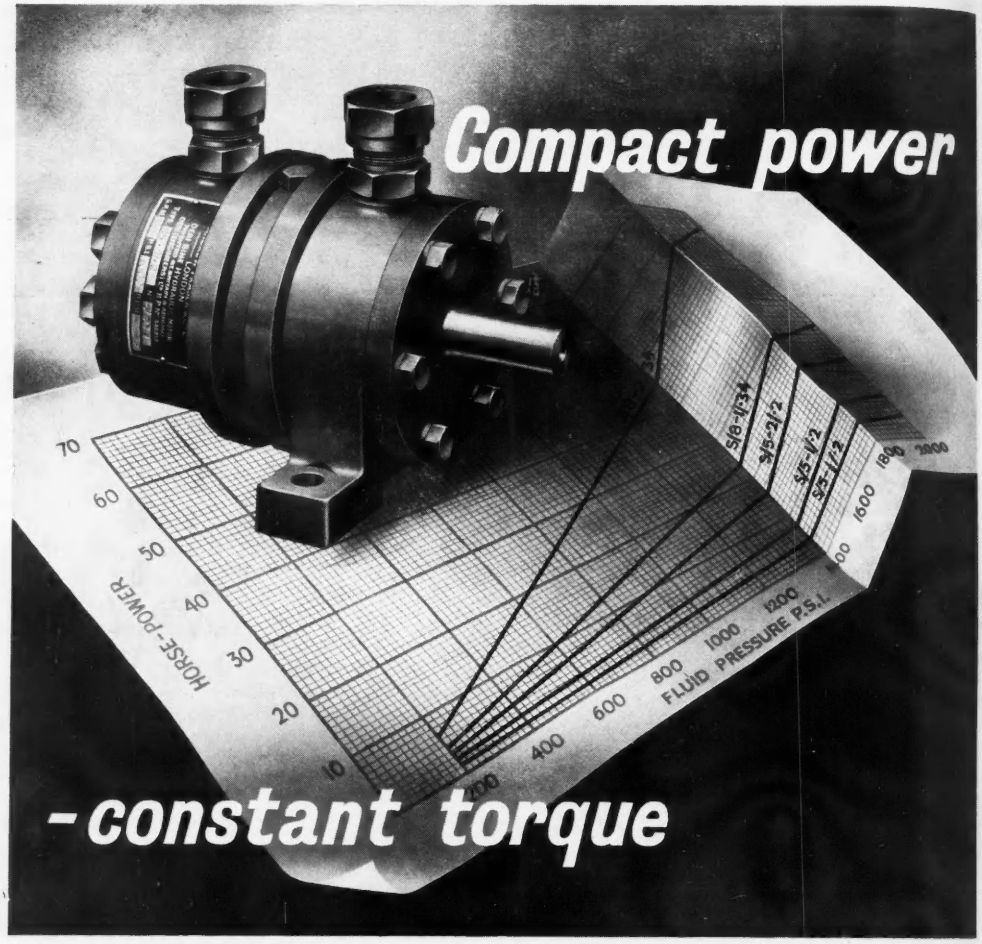


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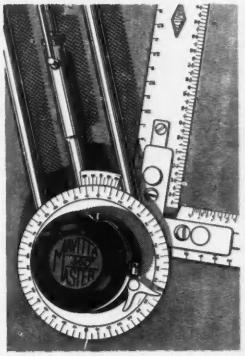

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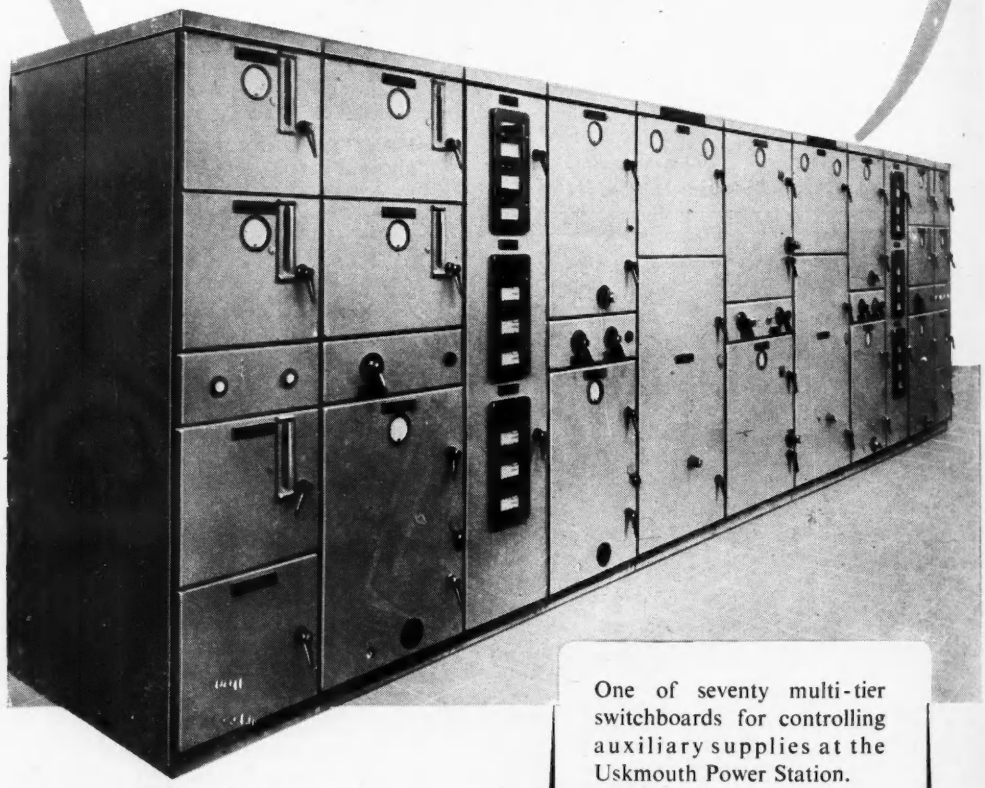

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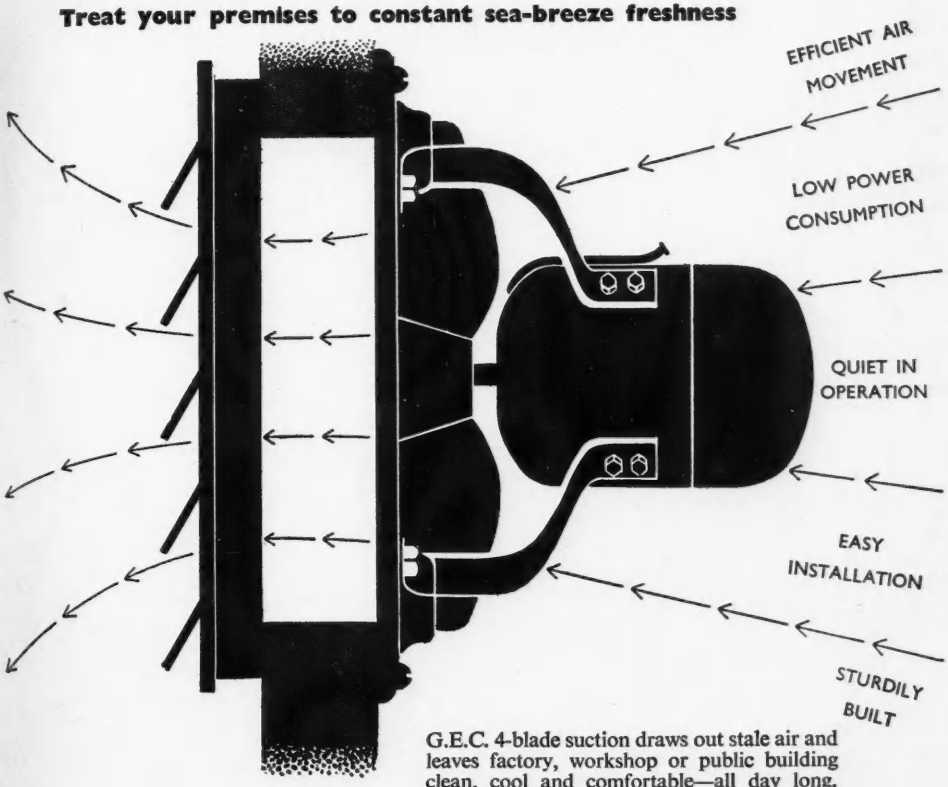


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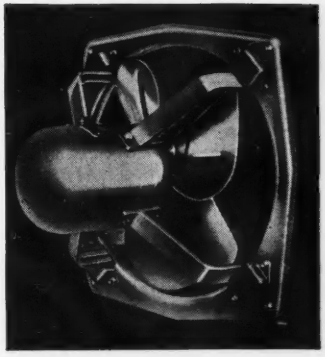

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Over 50 holes ranging from ¼" to 1.1/16" dia., are drilled and tapped in these cast steel coal cutter gear boxes. Because of their wide speed and feed range, simplicity of control and high penetration rates, ARCHDALE high speed radials assure maximum output on this and many other components in this factory. Sizes from 4 ft. to 7 ft. radius for drilling up to 3 in. dia., in steel.

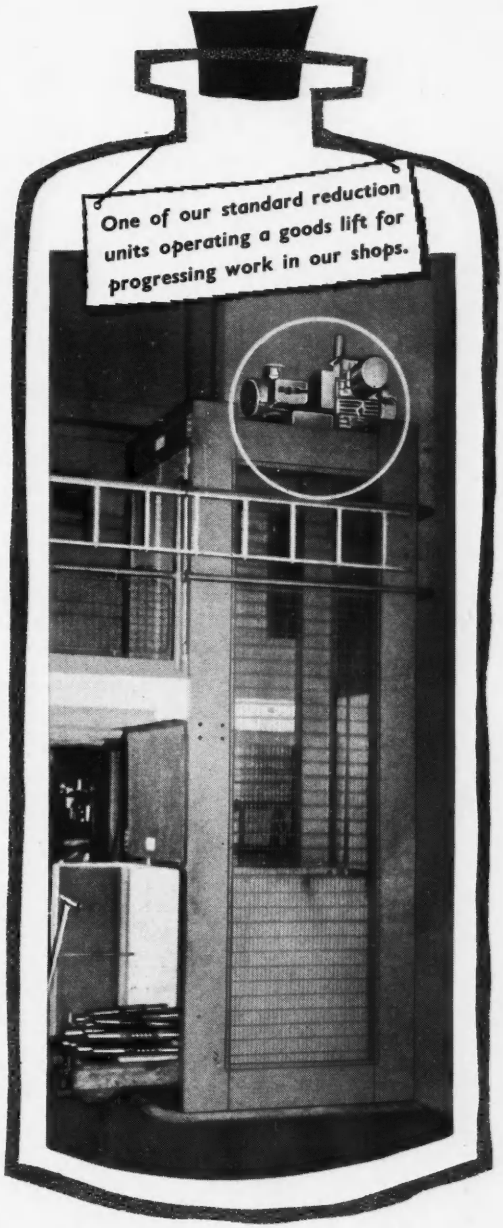
**JAMES ARCHDALE & CO. LTD. BIRMINGHAM 16 ● SOLE AGENTS: ALFRED HERBERT LTD. COVENTRY**

# Taking our own medicine

Our own Worm Units are busy at work all over our Milnrow factory. And you'd think someone had given us summat for nowt to see how pleased we are about it. It's partly pride—they're our *own* Worm Units—but mainly because they do the various jobs so very well. They're made to a formula which includes efficiency (a Holroyd Worm and Wheel hold the world record), reliability, and 50 years' experience. This prescription might do *you* a power of good, and it can be . . .

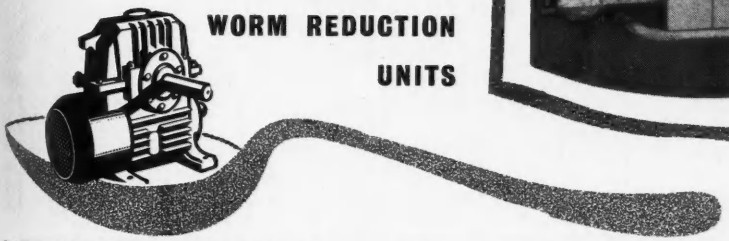
**MADE UP FOR YOU QUICKLY**

**A Standard Type Holroyd Worm Reduction Unit can be made up from stock, packed, despatched, and delivered to you fairly quickly. Worms, wheels, and special units made to order take somewhat longer. For information on Worm Units and applications (and we're discovering new ones every day, like the Goods Lift in the illustration) drop us a line at Milnrow, Lancs. We'll be glad to help you all we can.**




# Holroyd

**WORM REDUCTION UNITS**



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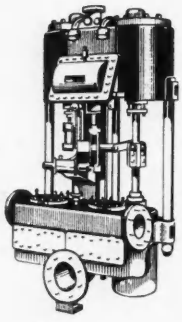
CRC 171



CROWTHORN *Lathes*

# SPEED THE PRODUCTION OF THOM, LAMONT PUMPS

Crowthorn lathes play an important part in the production programme of Messrs. Thom, Lamont & Co. Ltd. of Paisley.

A Crowthorn 15″ × 14′ 9″ gap bed lathe is engaged on general production work, machining components for the pumping equipment which is famous the world over.

Wherever accuracy and dependability are called for, Crowthorn lathes can be relied upon to give long and trouble-free service under all conditions.

A Crowthorn 15″ × 14′ 9″ gap bed lathe precision machining a removable gunmetal liner — a feature of these high-class pumps.

Lathe supplies by Messrs. Welling and Welling Ltd., 4 Victoria Street, London, S.W.1.

*Photograph by courtesy of Messrs. Thom, Lamont & Co. Ltd., Paisley.*

INTERNATIONAL MACHINE TOOL EXHIBITION 1956
June 22-July 6
Olympia · London

**STAND 28**
Ground Floor
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CROWTHORN
HIGH CLASS MACHINE TOOL MAKERS

**CROWTHORN ENGINEERING COMPANY LIMITED**
**REDDISH • STOCKPORT • ENGLAND**

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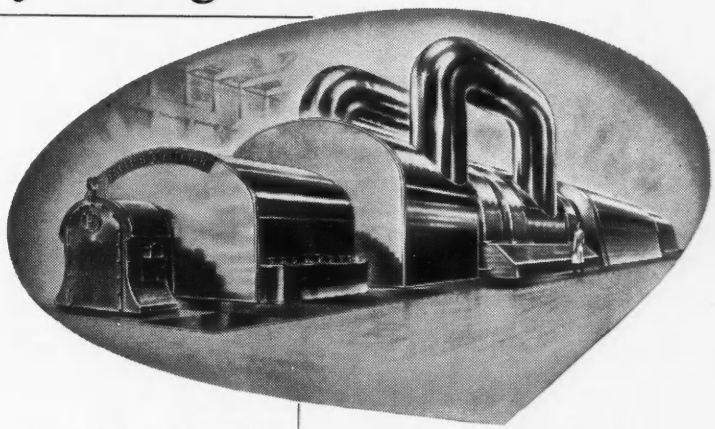
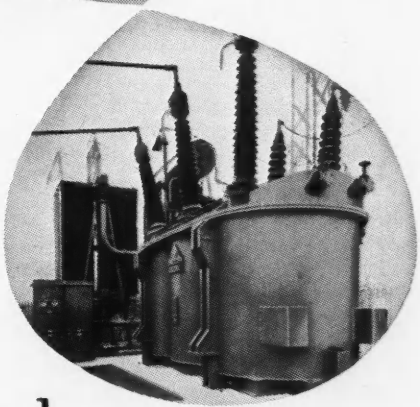
CL 66

# so many things...



This artist's impression shows one of three 200 MW turbo-generator sets now being built by 'ENGLISH ELECTRIC' for installation in the new power station which the Central Electricity Authority, subject to Ministerial consent, proposes to build on the River Trent at High Marnham. Each of these units is more than three times as powerful as the largest and latest 3,000 r.p.m. generating units yet in service in Britain and each will have a higher output than most of the complete power stations now operating.

The 275 kV transformer shown here was the first to be supplied to the Authority for service at this voltage.



# have made

# 'ENGLISH ELECTRIC'

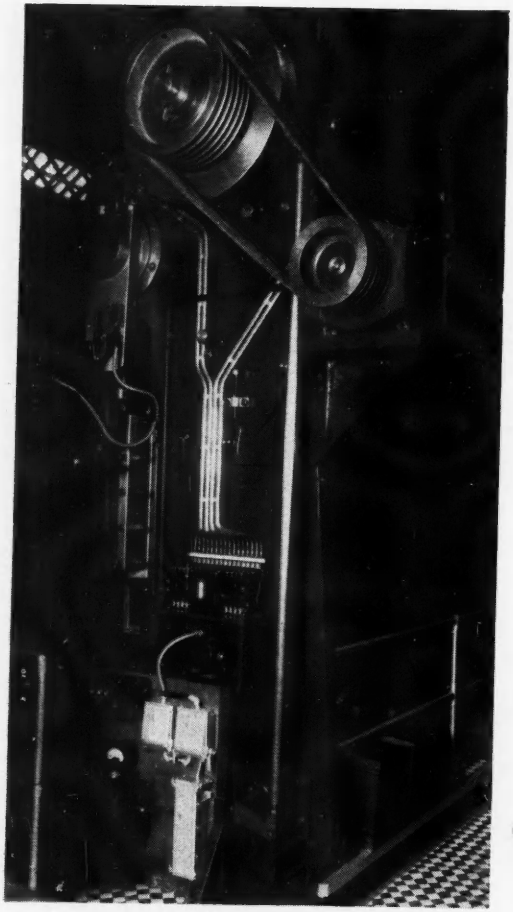
# famous

*Generating Plant—Steam, Hydraulic, Gas Turbine or Diesel. Transformers, Rectifiers, Switchgear and Fusegear. Industrial Electrification. Electric and Diesel-electric Traction. Marine Propulsion and Auxiliaries. Aircraft. Aircraft Equipment. Industrial Electronic Equipment. Instruments. Domestic Electrical Appliances. Television Receivers.*

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEENS HOUSE, KINGSWAY, LONDON, W.C.2.

*Offices and representatives throughout the world.*

P.52E



The Brentford System
fitted to a press manufactured by
Messrs. Taylor & Challen Ltd.

# Versatility in oil lubrication with the 'Brentford' system

The ' Brentford ' system of continual lubrication is entirely automatic. It is extremely versatile since each pumping unit—and there are from 1 to 24 of these—can be adjusted individually to deliver the right amount of oil to every bearing.

One pumping unit is used on each line or lubrication point, and the pump capacities are 1, 3 or 8 pints of oil. The ' Brentford ' can be driven in two ways; reciprocal or rotary off the machine or from its own Motor and Reduction Gear Box.

' Brentford ' Automatic Lubricators are at work in almost every industry, on many kinds of machine. Reductions in breakdowns have been estimated as up to 80%, with resultant increases in production and safety, and savings in the oil and power used.

The ' Brentford ' is one of the wide range of lubrication systems produced by Tecalemit and used throughout industry.

Tecalemit technical representatives are always ready with advice and information; fully experienced fitters handle any installation if required.

TECALEMIT
*The Authority on Lubrication*
PLYMOUTH, ENGLAND

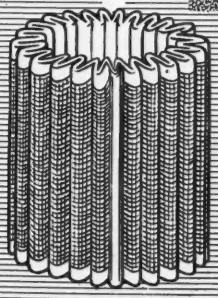
T327B

# THE FIRST FEW MINUTES

Does *filtered* or *unfiltered* oil reach the engine during the first few minutes after starting from cold? That is the vital question when considering the choice of filters—for this is the time when excessive wear can easily be caused.

Vokes Filters, with their high quality felt fabric elements, offer such low resistance that the direct flow device comes into operation for the absolute minimum of time. Yet, despite this low resistance, the highest standards of filtration are ensured at all times. Moreover, the unique design and flow principles of the Vokes filter ensure that no recirculation of trapped sludge can take place when the direct flow device is in operation, even under extreme conditions of service.

For the sake of the first few minutes . . . and of the years of service that follow, specify Vokes filters.



# VOKES

*pioneers of scientific filtration*

**VOKES LTD. Head Office: GUILDFORD, SURREY** London Office: 123, Victoria Street, Westminster, S.W.1

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V 134

# "This is our new representative!"

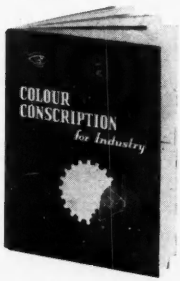
Incredible!

But is it more incredible to engage a "sloppy" representative than it is to encourage conditions which are a drag upon output?

There are many factories where such conditions do exist; where resources are being drained day after day and management seems unaware of it. Bad visual environment at bench or machine is a frequent cause of tiredness and fatigue; the worker is less alert, and the result is seen in greater spoilage, accidents, absenteeism.

By helping workers to *see* better, improvements in these conditions are quickly apparent. The way to do this is by *planned* colour. As all factories must be painted it seems sensible to use colour to the best advantage.

"Colour Conscription for Industry" shows how this may be done—and the results are frequently outstanding. May we send you a copy with our compliments?




**COLOUR ADVISORY SERVICE.** This department is staffed by artists trained in the principles outlined in "Colour Conscription."

Perspective drawings can be supplied for your guidance in following these principles; you are invited to make full use of this service.

**BRITISH PAINTS LIMITED**

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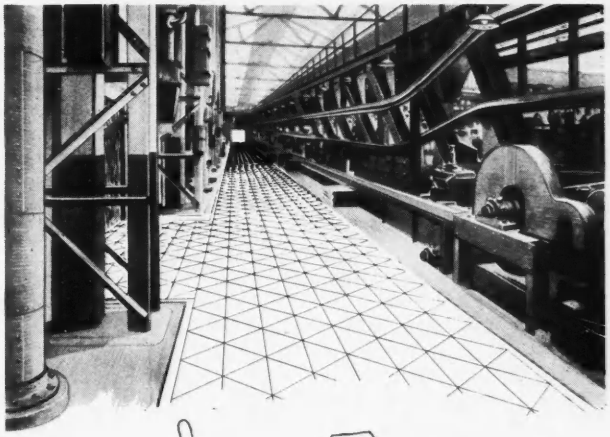

# Your factory is no place for crazy paving

Crazy paving is attractive in the right setting — but not in factories. Danger lurks in every crevice of badly laid flooring — danger to operatives and possible damage to equipment. A flooring which is speedily laid, mechanically level and above all, safe for *all* traffic is the Tri-Pedal Unit System of Iron Paving. It provides a permanent system of flooring which will stand up to the heavy wear and tear experienced in workshops and factories. Complete details of the Tri-Pedal System will be supplied on request.

**TRI-PEDAL** **Unit System of Iron Paving**

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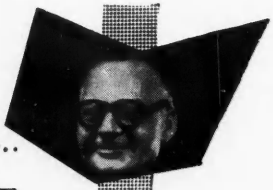

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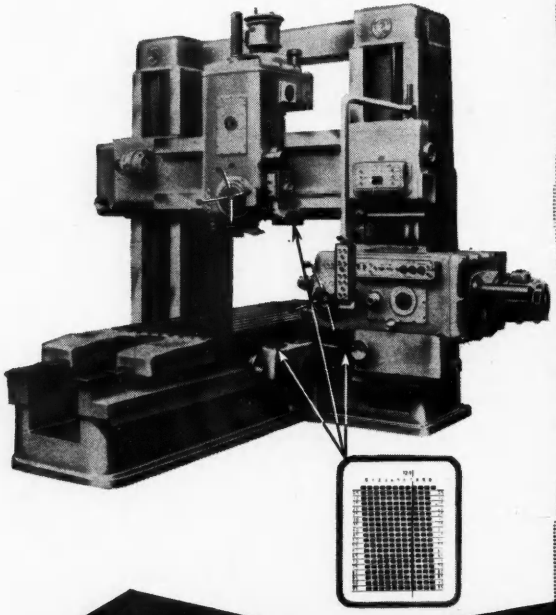
# THE LARGEST VERSATILE HORIZONTAL AND VERTICAL JIG BORER IN THE WORLD



## THE KOLB OPTICAL CO-ORDINATE JIG BORER No. 150 V.H.

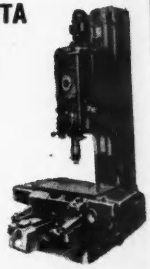
•

***OUTSTANDING FEATURES***

**Optical Setting to .0001". Work capacity 47" x 79" x 54" approximately. Rapid movements in all directions. Available as vertical or horizontal machine only.**

**TYPE OPTA 120**

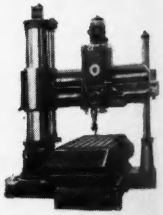
—Table size 24" x 48"

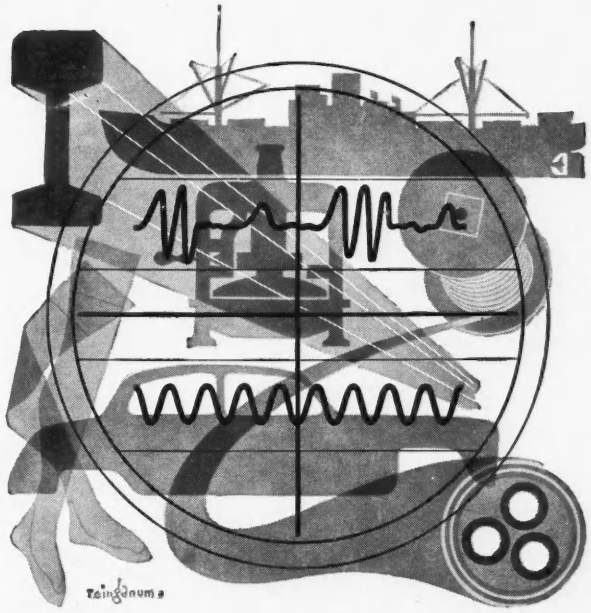


*And for smaller work . . .*

**TYPE OPCO 175**

Table size 40" x 70"





# The Cossor oscillograph may save you time and money

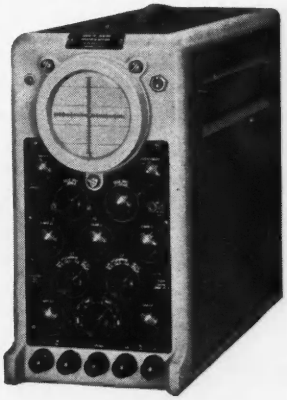
Cossor Oscillographs are not confined to the analysis and measurement of purely electrical quantities, for with these instruments you can translate mechanical motions into electrical signals. Such signals can then be displayed on the screen of the oscillograph for evaluation. Cossor Oscillographs are being used in a wide variety of industries, not only for research but for testing, checking and quality control of the product from its design stage to its final assembly.

*The following are just a few industries which—to their advantage —are now using Cossor instruments:*

**SHIPBUILDING . CABLE MAKING**
**AUTOMOBILE ENGINEERING · RAILWAYS**
**TEXTILES · PRINTING AND PAPER MAKING**

**It may well be that we can help you in your industry.**

*The Technical Advisory Staff of the Cossor Instrument Division is always at your service.*



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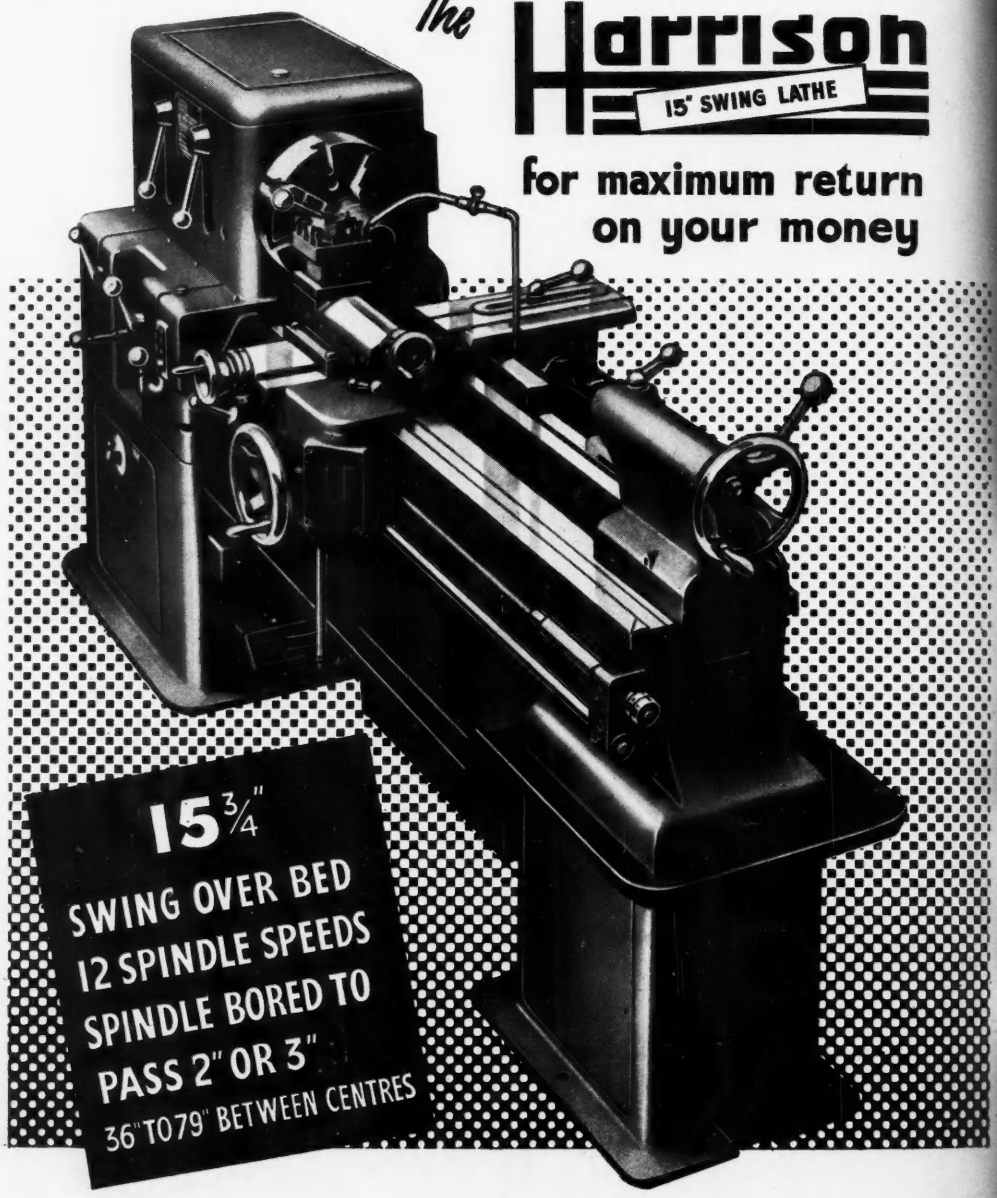
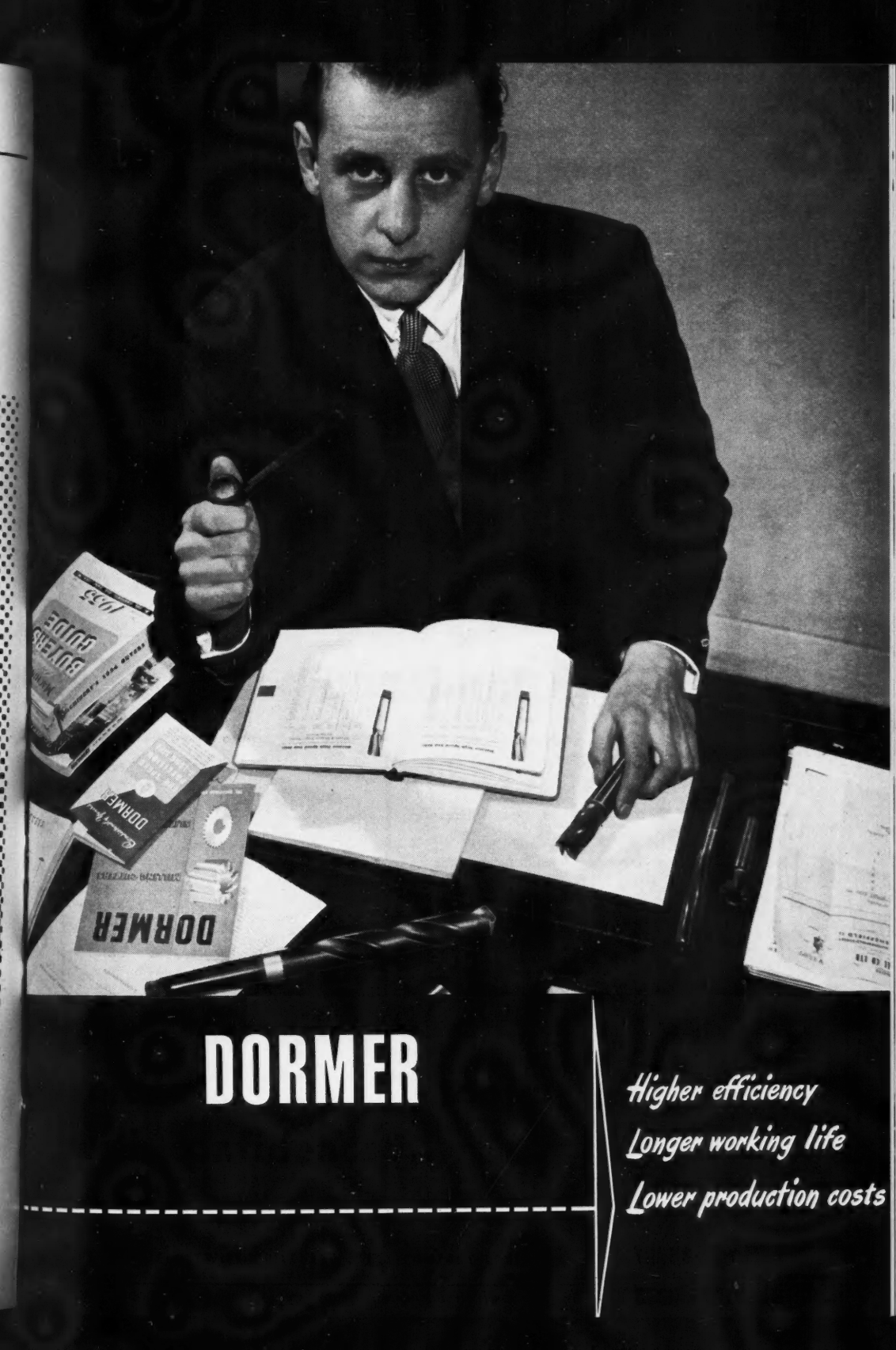
15" SWING LATHE

**for maximum return on your money**




● **Whether you need increased plant for Toolroom or general production work a Harrison Lathe is a sound investment.**

**T. S. HARRISON & SONS LTD., HECKMONDWIKE, YORKS.**

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*Higher efficiency*
*Longer working life*
*Lower production costs*

**BRADY SHUTTERS** | **ROLLING DOORS** | **SHUTTER THE WORLD**

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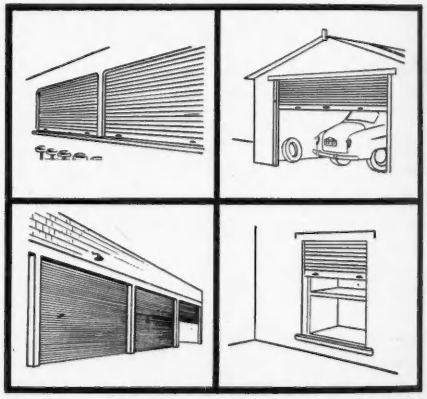
The "Princess of Vancouver", one of the most modern ferry boats in the World, recently built on the Clyde, has Brady electrically-operated Rolling Doors fitted, to the Car and Rail entrance for added safety, fast and easy operation and to save space.

These three qualities, plus greater strength, better appearance and absolute reliability, have made Brady products famous throughout the World—in factories, hotels, garages, bus depots, railway yards, vehicles, etc.

There is a Brady Rolling Door, hand or electrically operated, suitable for the project you are engaged upon. Full details, and free descriptive literature—write to the addresses below.

*The doors commanding the world's largest sale.*



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# For the 3rd year running...

**AN IC-EQUIPPED GENERATING STATION HEADS THE CEA THERMAL EFFICIENCY TABLE* WITH A RECORD EFFICIENCY**

* For the 12 months period ending March 31st 1955

**OTHER IC-EQUIPPED GENERATING STATIONS HIGH ON THE LIST:**
Littlebrook "B" 30.49%
Skelton Grange 28.89%
Brunswick Wharf 28.70%
Poole 28.31%

## TOP PORTOBELLO H.P.

**—for the second consecutive year, with a thermal efficiency of 31.42%**

Firing equipment with a total generating capacity of 8,000,000 lbs steam/hour was supplied to the C.E.A. alone by IC, during the year.

***Facts like these speak for themselves***

Europe's Largest Generating Station. The contract for complete steam generating plant at High Marnham, was recently awarded to International Combustion.

**INTERNATIONAL COMBUSTION LIMITED**

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T.G. SG.54

# Having a hand in Productivity

IN EVERY INDUSTRY OR TRADE, electrical equipment is the key to modern production methods. There are probably more production-boosting and money-saving devices than you know of. Your Electricity Board can help you and give you sound advice.

They can also make available to you, on free loan, several films on the uses of electricity in Industry — produced by the Electrical Development Association.

E.D.A. are publishing a series of books on "Electricity and Productivity". Four titles are available at the moment; they deal with Higher Production, Lighting, Materials Handling, and Resistance Heating. The books are 8/6 each (9/- post free) and the Electricity Boards (or E.D.A. themselves) can supply you.

## One man fires 12,000 dozen pieces a week

*He does it electrically — in a multi-tunnel kiln. There are 16 tunnels and the ware in adjacent tunnels travels in opposite directions so that the incoming ware picks up heat from the outgoing. The ware is pushed through each tunnel in a series of pre-determined steps, controlled electrically. All the operator has to do is to feed the ware into the kiln and take out the finished pieces — 144,000 of them a week. Biscuit firing, glost firing or decorating, tea ware, dinner ware, tiles or 'fancies' — the electric kiln does it all. Higher output at low heating cost per article is*

**only one of the aids to higher Productivity that Electricity can bring you.**

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**The British Electrical Development Association**
*2 Savoy Hill, London, W.C.2*

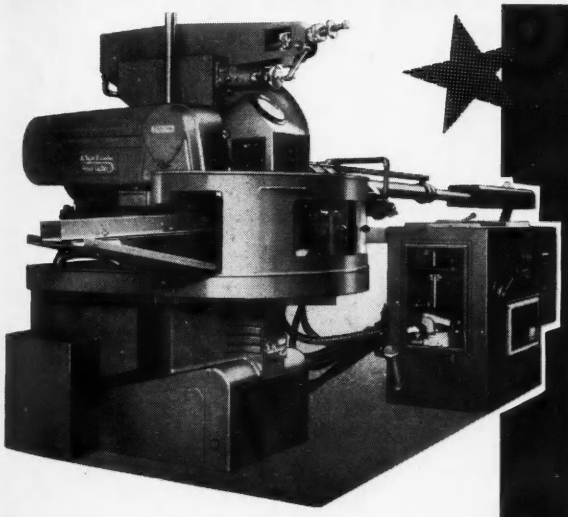
INSTANT, EASY CUTTING-OFF

*on most materials—*
*even the hardest*

*—with the new* **Ballinger**

**WET-TYPE ABRASIVE WHEEL**

# CUTTING-OFF MACHINES



**ILLUSTRATING TYPE 'A' FULLY AUTOMATIC SINGLE BAR HYDRAULICALLY OPERATED MODEL CAPACITY 3in. SOLID BARS WITH 16in. WHEEL**

**OTHER MODELS AVAILABLE WITH CUTTING CAPACITIES UP TO 8in. SQUARE OR 72in. by 4in. SLABS**

***Full details forwarded on request***

**L. J. H. BALLINGER LTD.**
WOODCHESTER, STROUD, GLOUCESTERSHIRE

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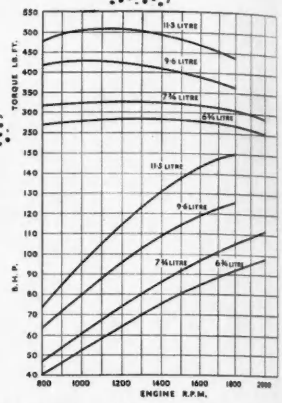
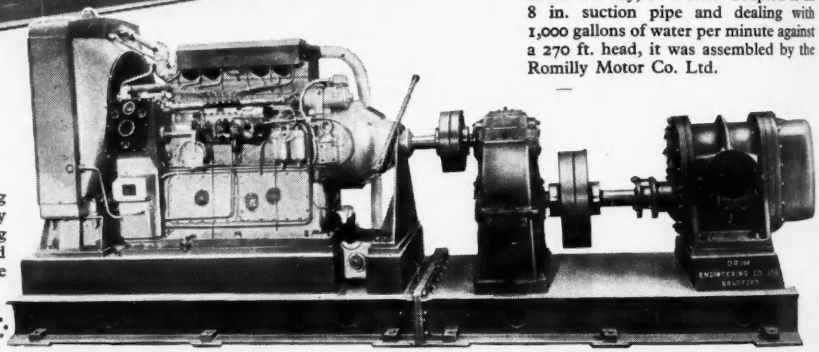
# Portable Power

Why do so many contractors prefer A.E.C. diesel engines for portable pumping units? First—A.E.C. diesels are light in weight, essential when moving from job to job. Secondly—they're compact—an important point where portability is a "must". A.E.C. diesels are economical too—ask the man who runs one! But more than all this, when you invest in an A.E.C. diesel you invest in year-round reliability that is built into every A.E.C. engine. With an unrivalled background of engineering experience and a world-wide spares and maintenance service you can always rely on A.E.C.




This Mather & Platt Pump, powered by a 9.6 litre A.E.C. diesel engine, is used by Sir John Jackson Ltd., for draining excavations on the N.C.B. open cast coal site at Carway, S. Wales. Coupled to an 8 in. suction pipe and dealing with 1,000 gallons of water per minute against a 270 ft. head, it was assembled by the Romilly Motor Co. Ltd.



This fuel bunkering pump unit was made by the Drum Engineering Co. Ltd., and is powered by an A.E.C. 9.6 litre diesel engine.

## Specify A.E.C. DIESEL ENGINES

THEY SAVE MONEY IN THE LONG RUN

A.C.V. SALES LTD., MARINE & INDUSTRIAL DIVISION, A.E.C. WORKS, SOUTHALL, MIDDLESEX

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The A.C.V. Group of Companies includes: A.E.C., CROSSLEY MOTORS and the MAUDSLAY MOTOR CO.

THE TORCH OF INDUSTRY

# THE BEAGLE

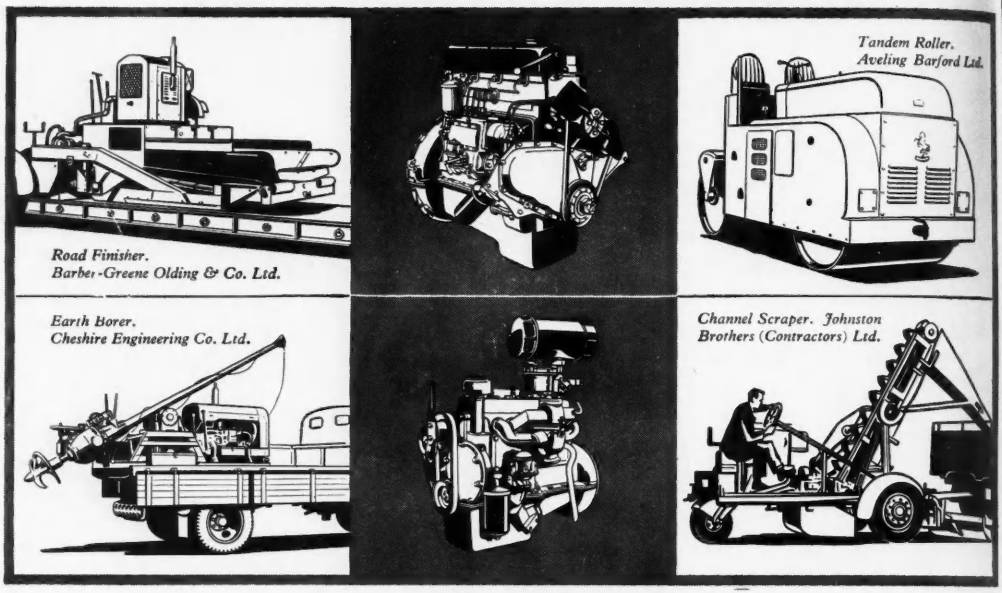
***A transportable profiler that cuts constant angle bevels automatically on curves of any radii***

You can carry the Beagle—all up weight 125 lbs.—to the job and set it up to cut in a few minutes. Electrically driven and guided by a hand steered tracing wheel, it will cut any profile in steel up to 2″ thick, operating direct from working drawings with the greatest accuracy. No waiting for the work to come to the machine—no expensive templates needed. *And* the Beagle is fitted with a unique cutter which will maintain any bevel up to 45° round any profile.

**For full details please write for the 'Beagle' leaflet to the Sales/Service Department of British Oxygen Gases Ltd. at Bridgewater House, St. James's, London, S.W.1.**

BRITISH BOC OXYGEN

# FORD INDUSTRIAL ENGINES for POWER and ECONOMY



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*Barber-Greene Olding & Co. Ltd.*

*Tandem Roller.*
*Aveling Barford Ltd.*

*Earth Borer.*
*Cheshire Engineering Co. Ltd.*

*Channel Scraper. Johnston Brothers (Contractors) Ltd.*

Illustrated above are but a few of the many uses of Ford industrial engines. These versatile units are giving long service with traditional Ford economy in many fields of operation. Everywhere the Ford Dealer Organisation is readily available for their efficient maintenance.

**DETAILS OF DIESEL, PETROL AND VAPORISING OIL ENGINES ARE GIVEN BELOW:—**

| DETAIL | 102E Petrol 1172 cc. | 202E Petrol 1508 cc. | 203E Petrol 2262 cc. | 500E Petrol 4-Cyl. | 563E Diesel 4-Cyl. | EIADN Petrol 4-Cyl. | EIADKN Pet/V.O 4-Cyl. | 954E Diesel 4-Cyl. |
|---|---|---|---|---|---|---|---|---|
| BORE MM. | 63·5 | 79·37 | 79·37 | 100 | 100 | 95 | 100 | 100 |
| STROKE MM. | 92·5 | 76·20 | 76·20 | 115 | 115 | 115 | 115 | 115 |
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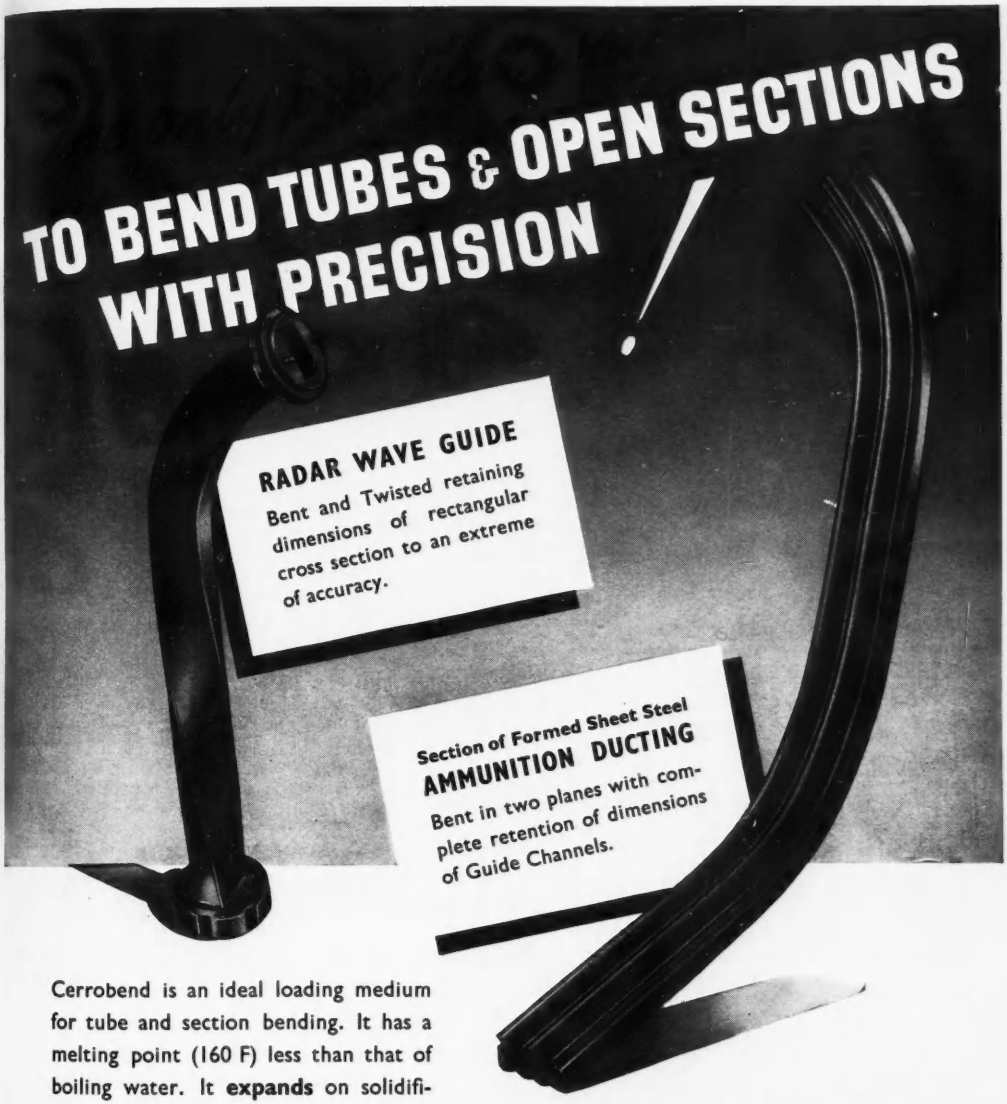
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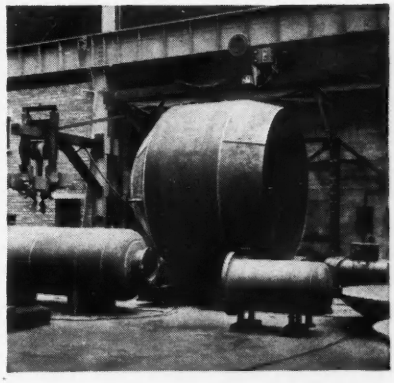
*The Lincolnweld process is explained in a brochure available from Dept. C.*



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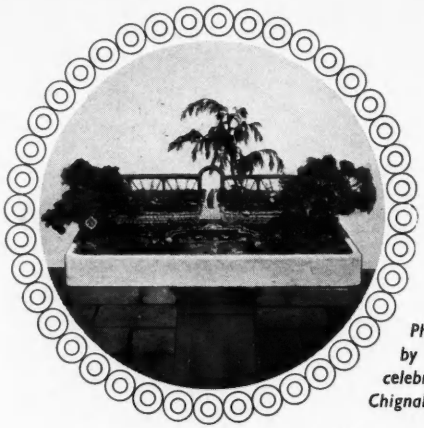

*Photograph of Miniature Garden by courtesy of Anne Ashberry, celebrated Miniaturist Gardener of Chignal Smealey, near Chelmsford.*

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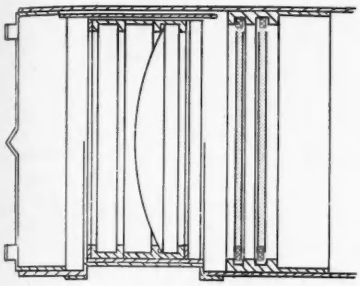

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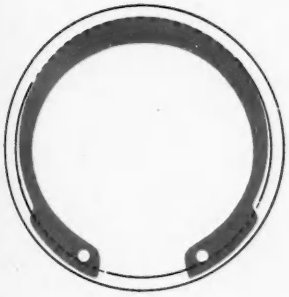

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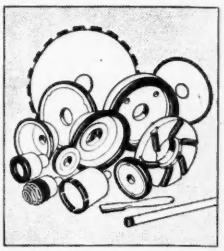

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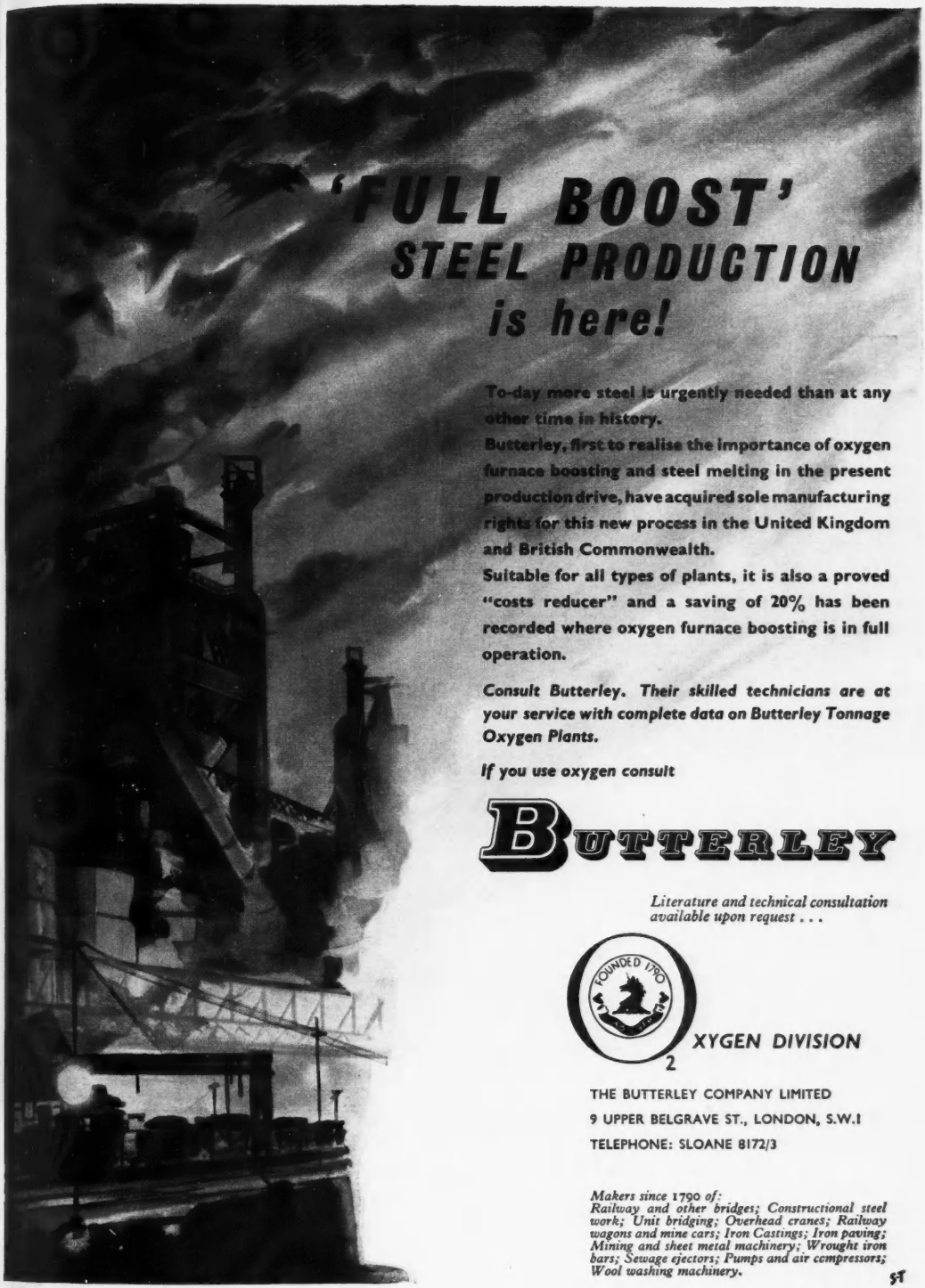

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## *silicone rubber*

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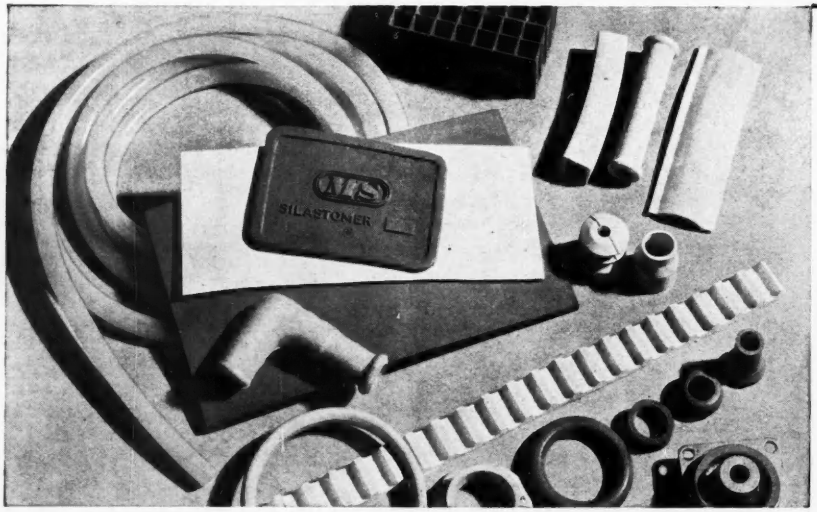


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**24 hrs. at 300° F.**

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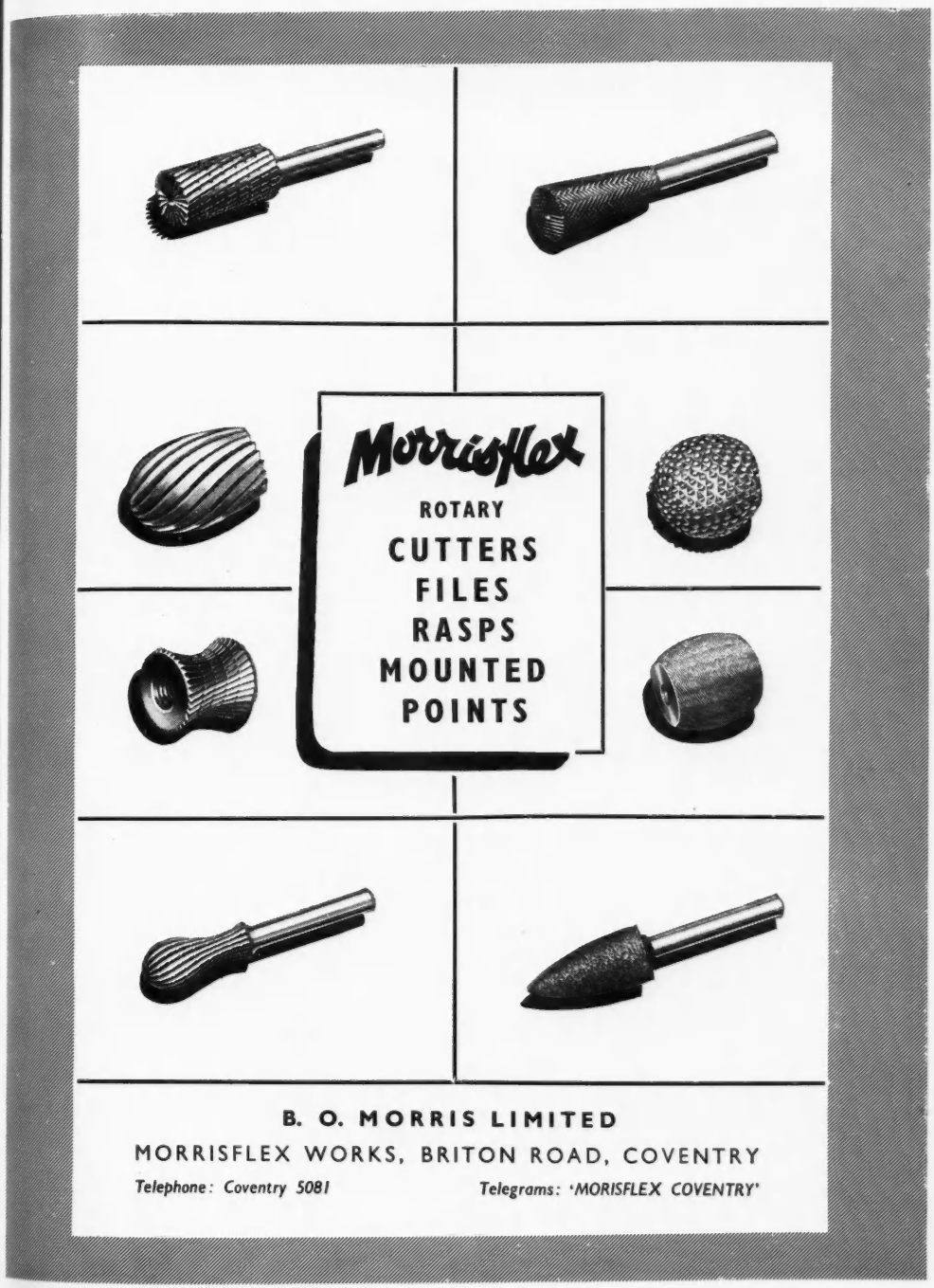
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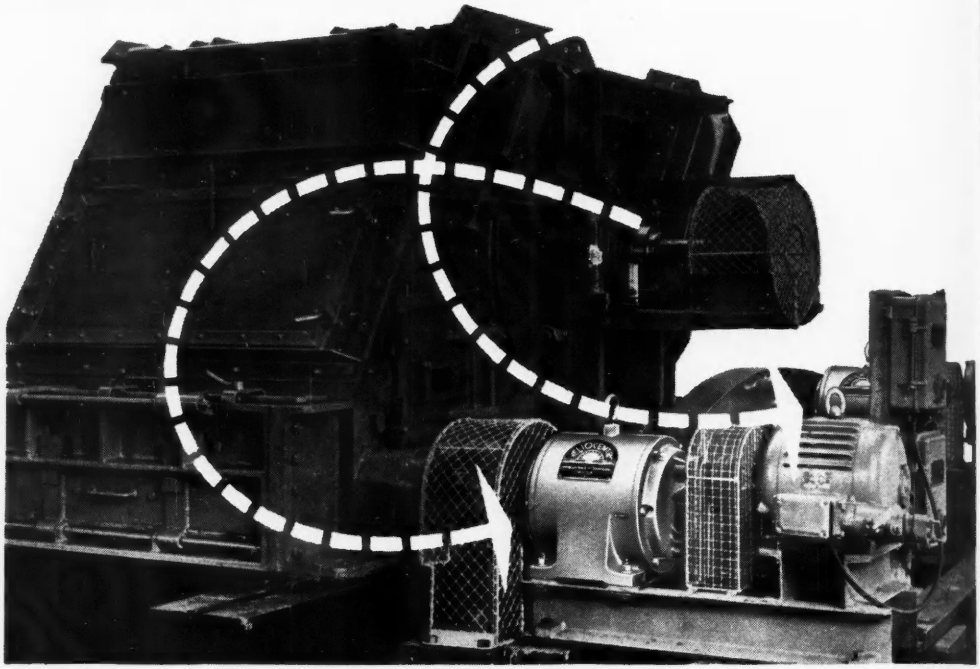

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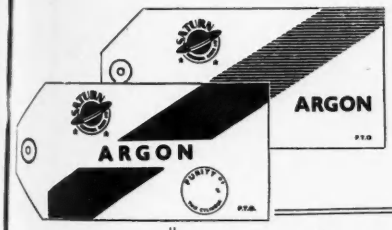


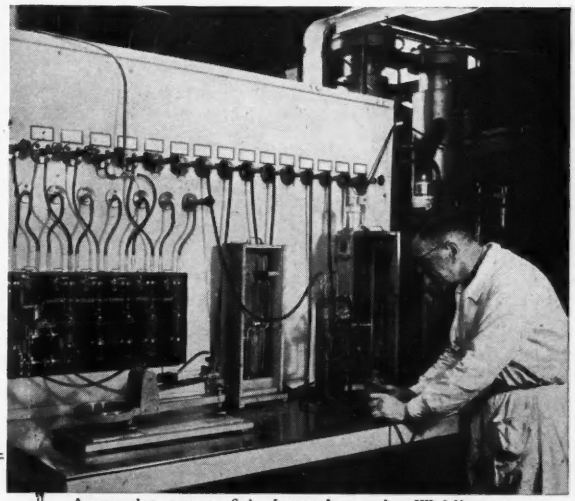

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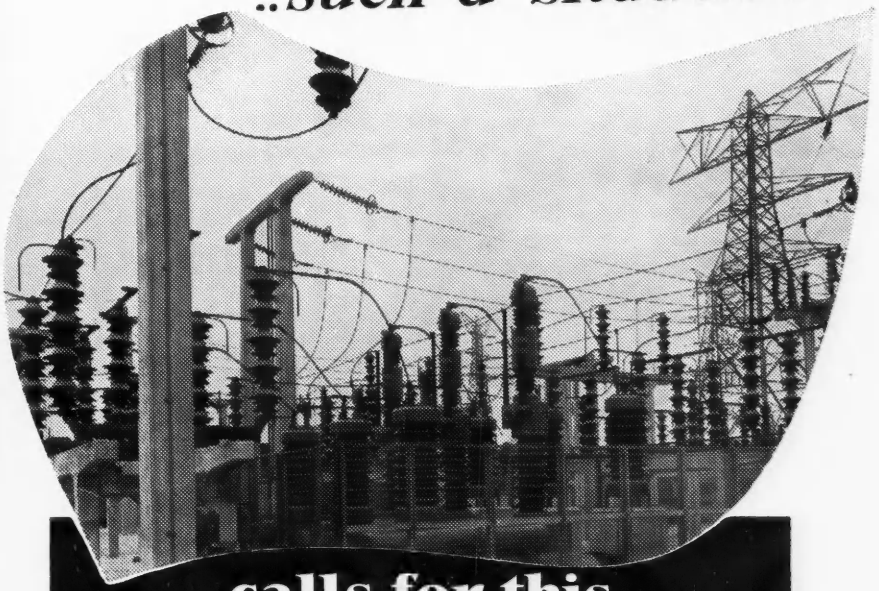

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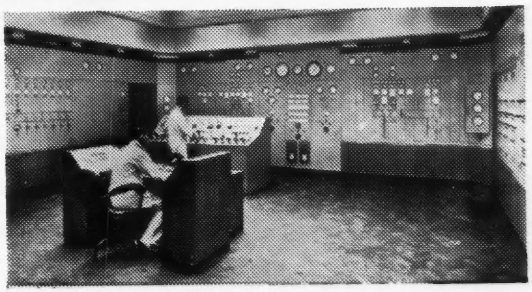

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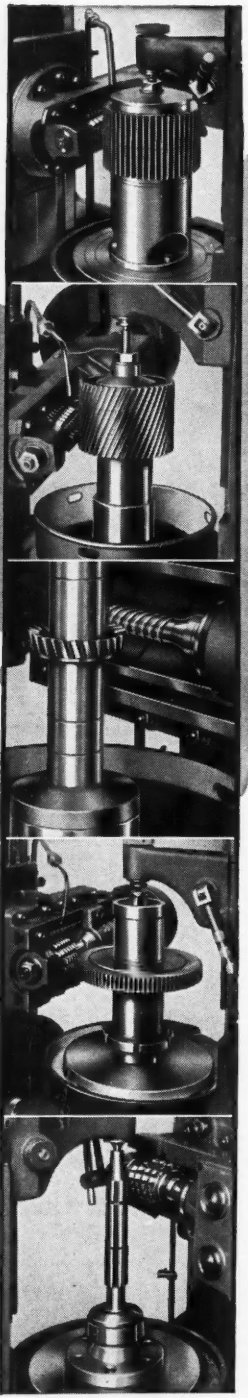

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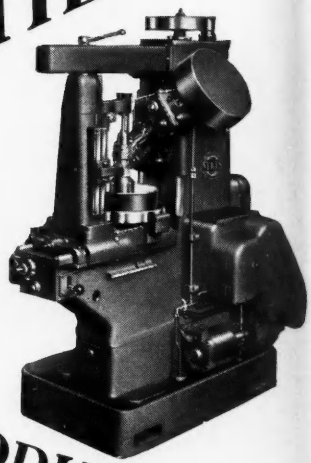

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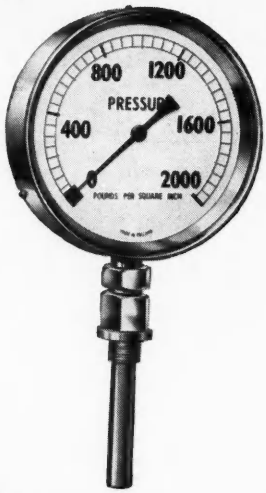


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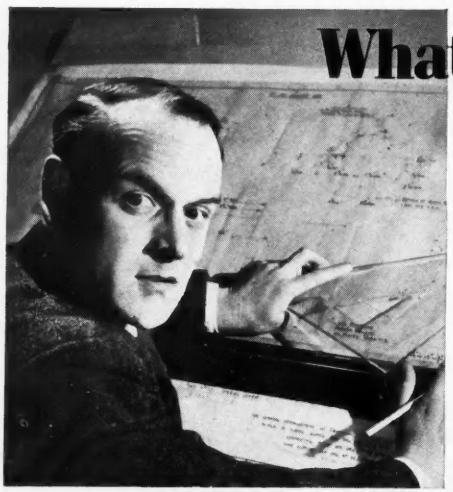

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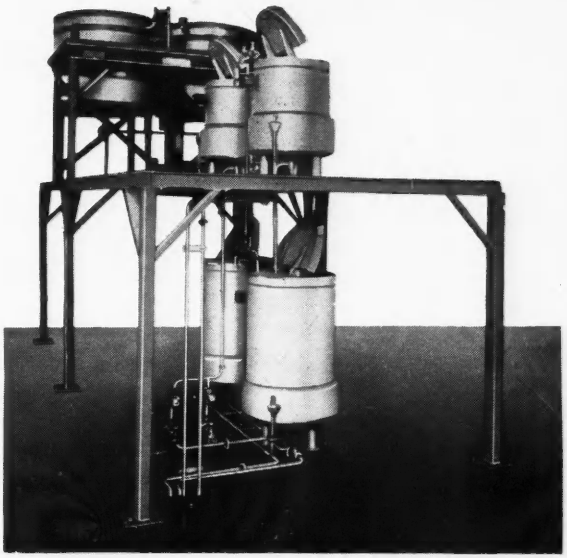

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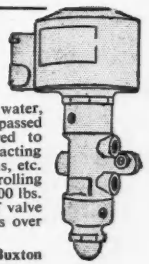

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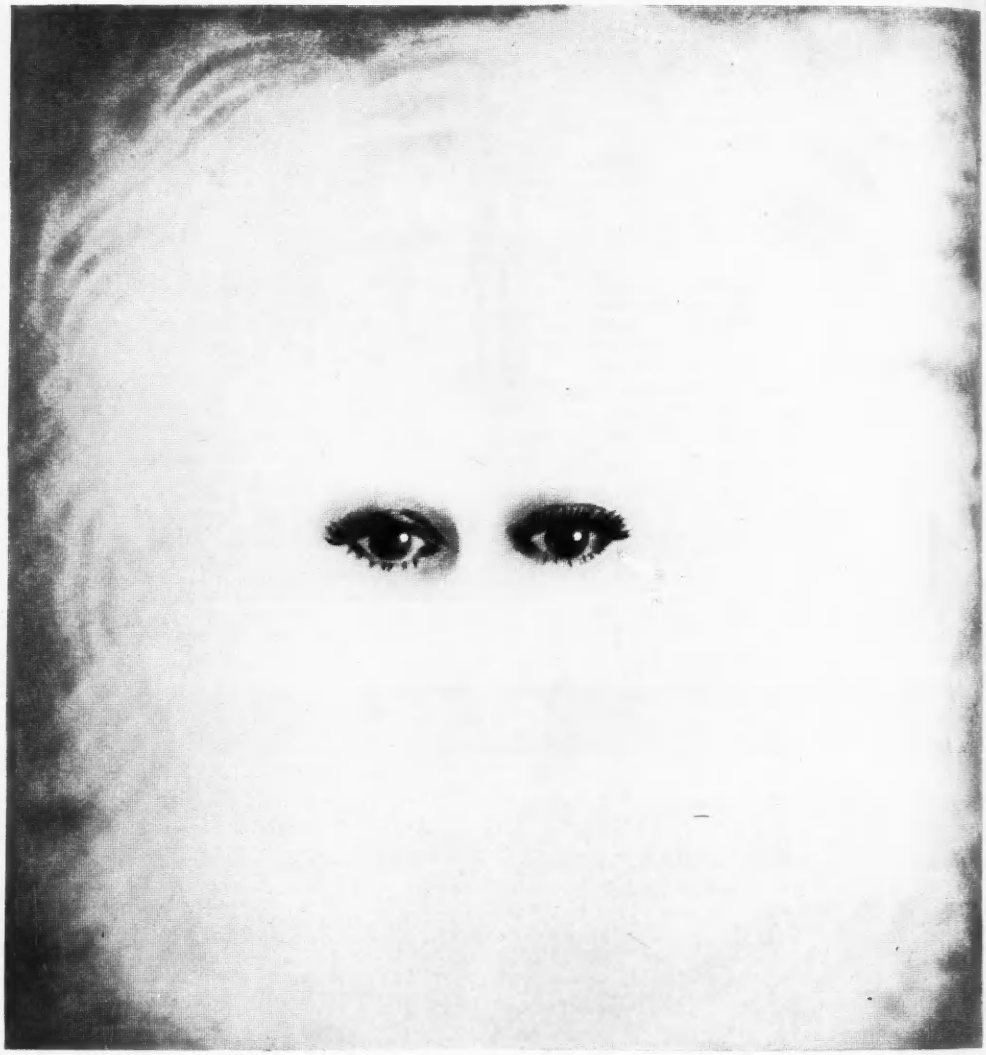

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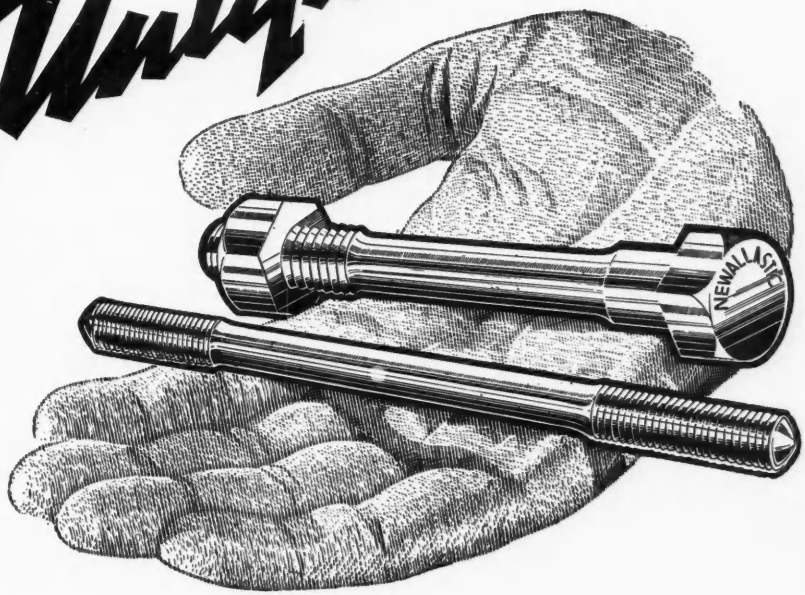


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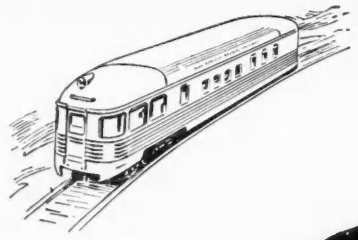

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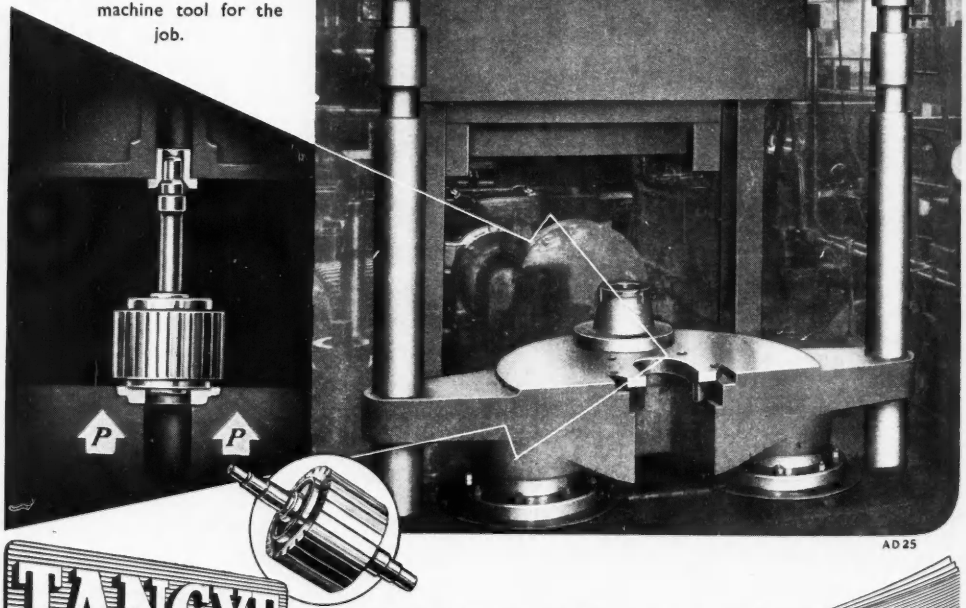


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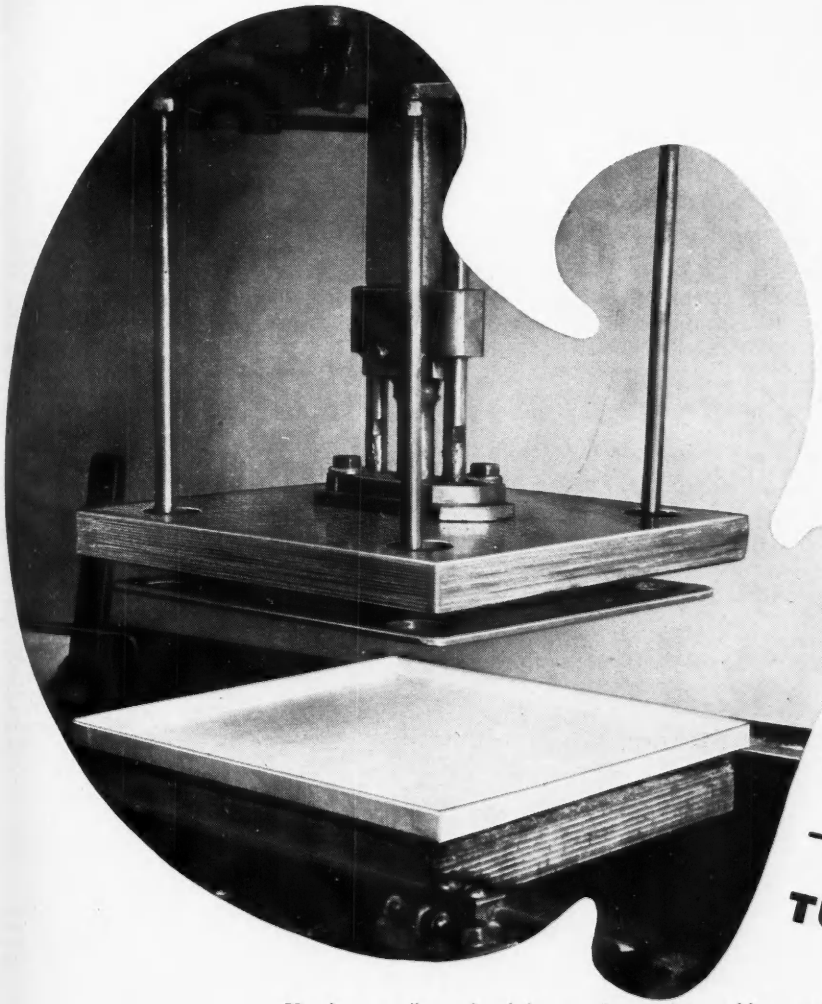

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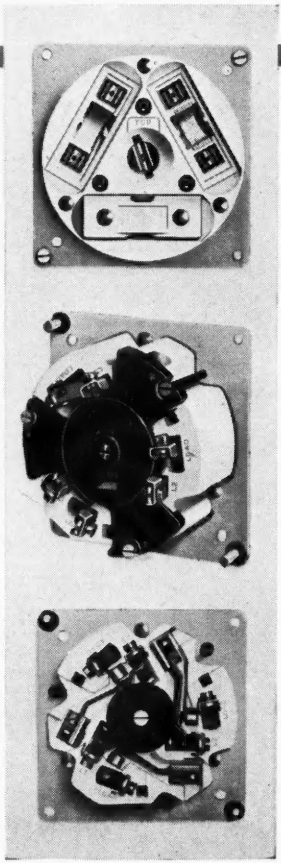

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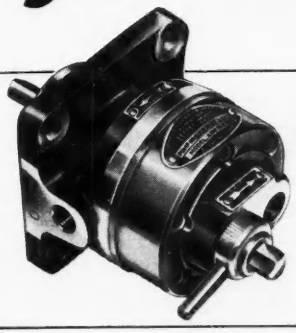

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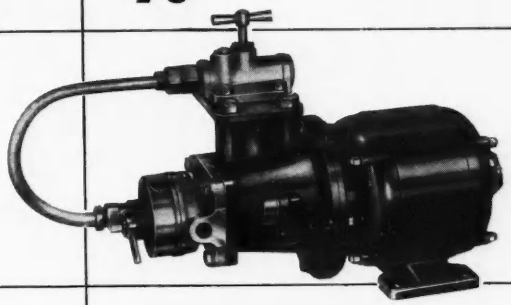

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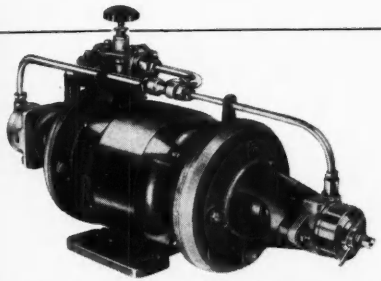

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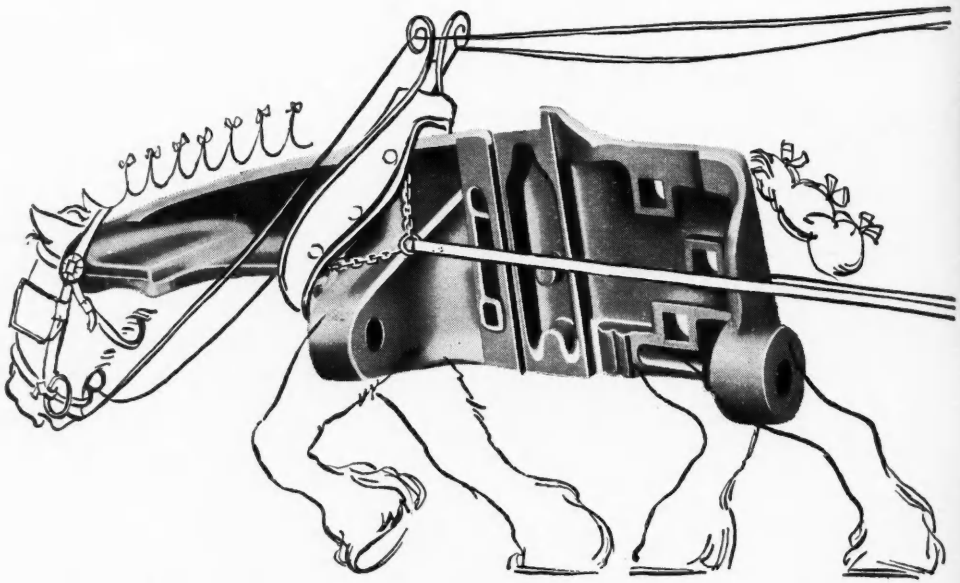

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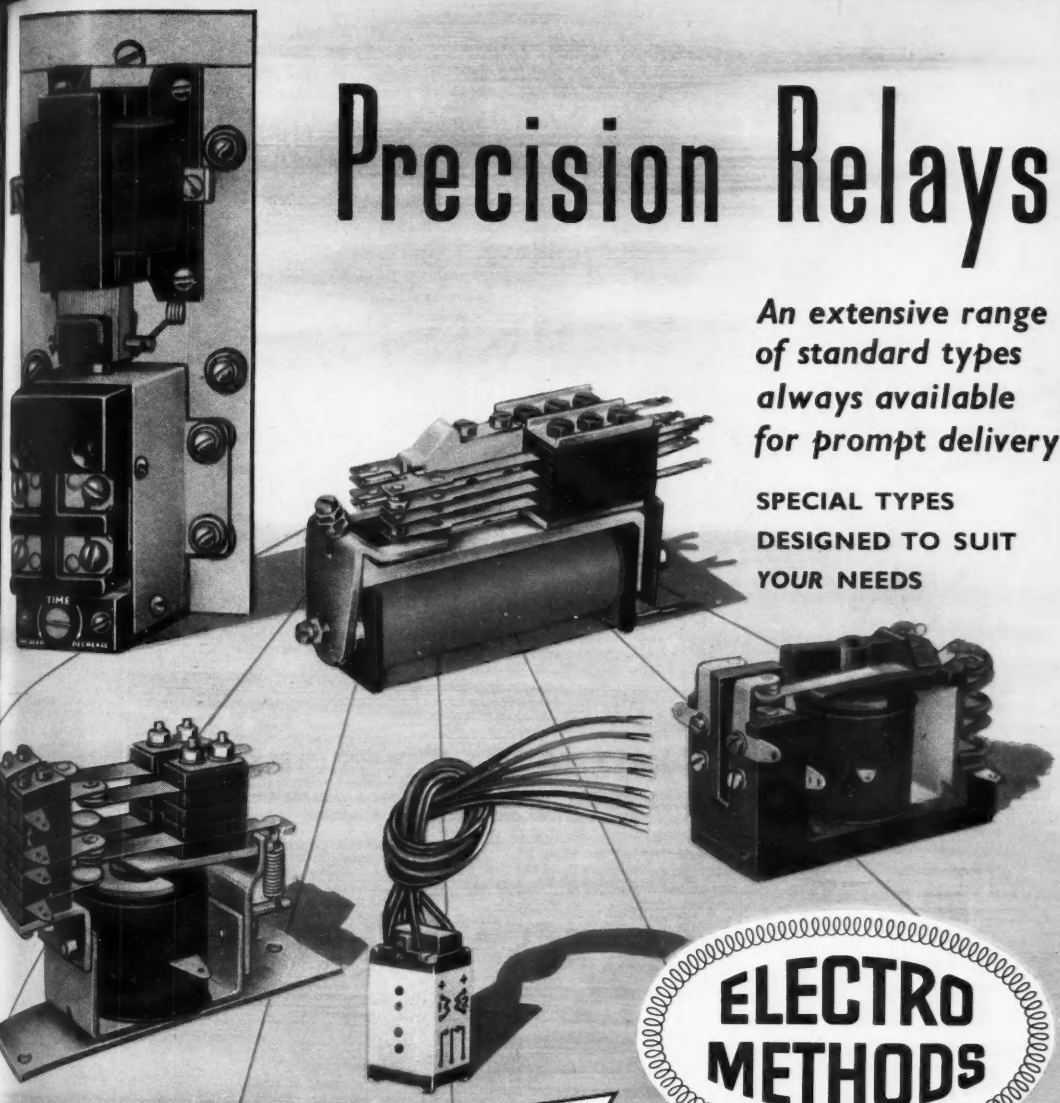

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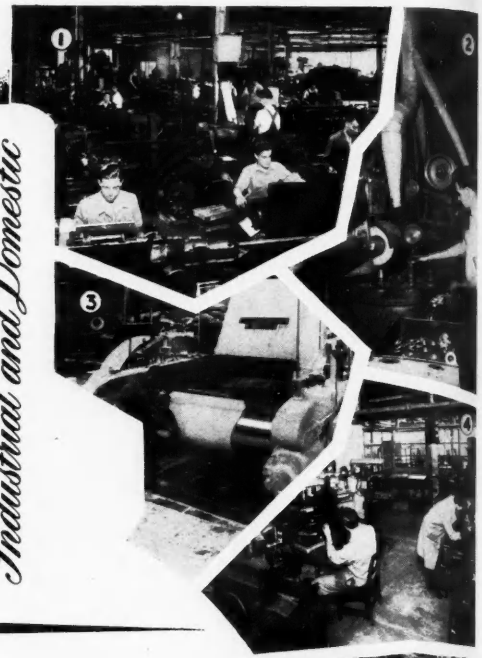

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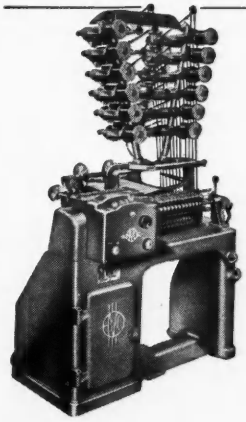

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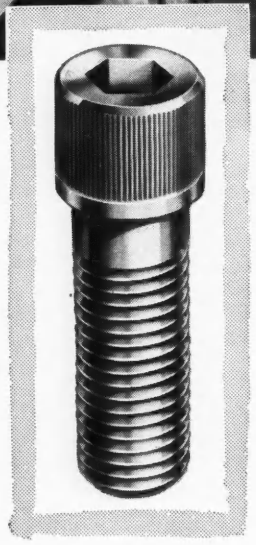

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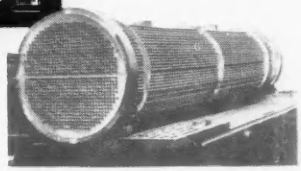

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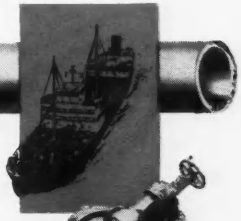

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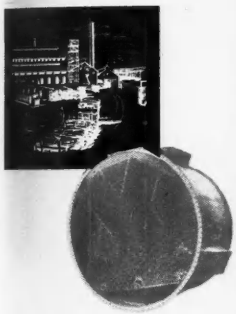

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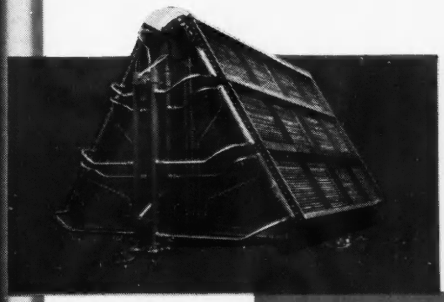

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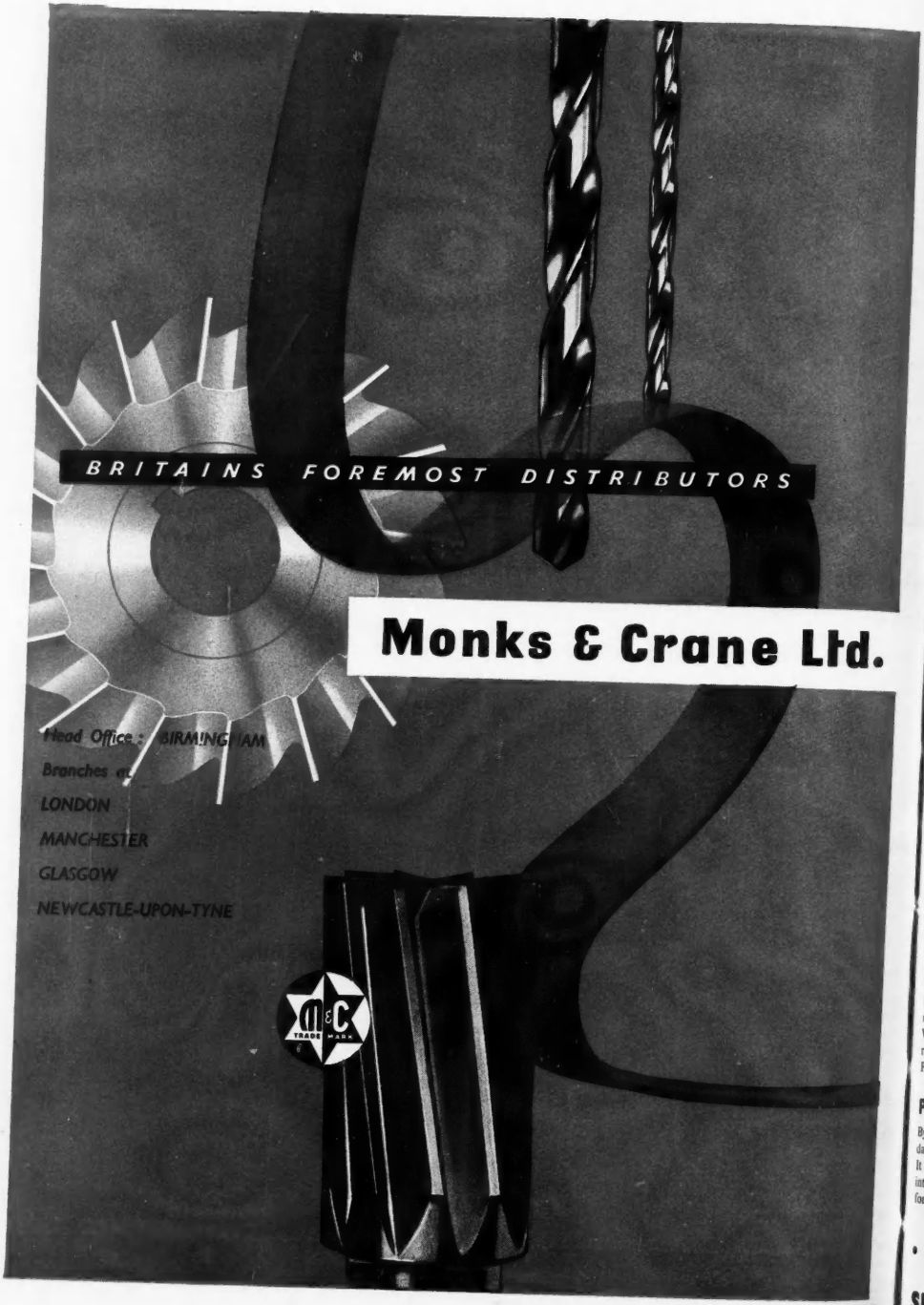
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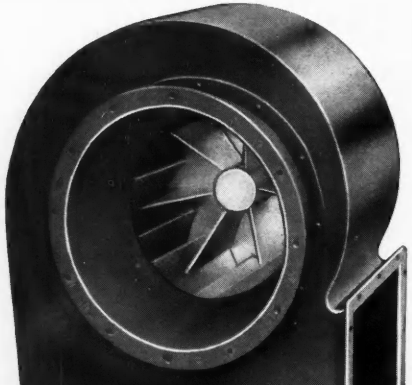

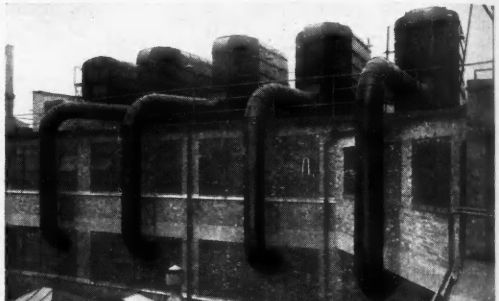

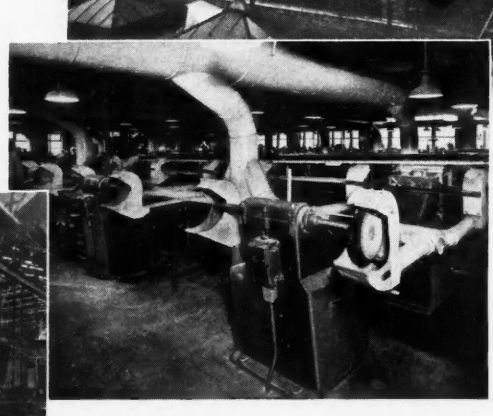

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*Illustration, top right, shows a large Dust Collecting plant in the Midlands.*
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*Bottom, Fume removal from cyanide pots at The Standard Motor Co. Ltd.*

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# THE BLUE PAGES

## A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

### ● *TIN-ZINC ALLOY PLATING*

A recent paper discusses the merits of the tin-zinc alloy plating process with regard to its application in general and to the coating of copper wire in particular. As the authors point out, a plating bath for carrying out this process, characterized by good stability, operability, and tolerance for plant conditions, was developed some seven years ago. It was proved that tin and zinc can be co-deposited in practically any desired proportions. After a careful study of the system and of the properties of various electrodeposited alloys, it has been found that the composition of 75% tin and 25% zinc produces best results. The authors emphasize that spray and outdoor exposure in both marine and industrial environments have indicated the good corrosion resistance of this composition. In fact, it is far superior to pure tin in protecting the underlying steel. In comparative tests of tin versus tin-zinc on copper exposed for two years to severe marine environment, copper panels electroplated with a 0·00035-in. layer of tin were completely covered with corrosion products within two months, and at the end of one year the surface had taken on a greenish colour, indicating corrosion of the underlying copper. Similar panels plated with the same thickness of tin-zinc showed very little corrosion at the end of a year, and only after two years began to turn slightly green. In the wire industry acceptability of the tin coating is measured by the polysulphide dip test. Electroplated coatings of tin on copper wire must be about 15 millionths of an inch thick, and it is reported that tin-zinc coatings of comparable thickness also passed this test easily.

### ● *FRICTIONAL CHARACTERISTICS OF PLASTICS*

According to a recent report, the frictional characteristics of seventeen plastics have been investigated. Many of the plastics tested showed evidence of exceptionally good frictional characteristics, even when running dry. Outstanding in this respect are the Teflon-type materials, especially at low speeds. The structural and thermal characteristics of Teflon can be changed by adding fillers, without sacrificing low friction values. This was also found to be the case with nylon and graphite-filled nylon. Other comparatively low friction values were obtained with polystyrene run dry at high speed, cellulose acetate and polyethylene with water lubrication, cellulose acetate butyrate with water lubrication at high speed, and polyethylene with oil lubrication. The friction coefficients were usually found to decrease with an increase in applied load. The most likely explanation for this effect involves elastic deformation at light loads and plastic deformation at high loads. Increased speed, especially under dry conditions, results in either a drop in friction or an initial rise followed by a drop. For this effect, a theoretical explanation is advanced which involves the combined effects of stick-slip and shearing at low speeds, and the effect of shearing only at high speeds. In general, friction values were found to drop as lubrication is changed from dry to water to oil. Two exceptions were found, i.e., a polytrifluorochlorethylene product and methacrylate, which showed no changes in friction values when changing from dry to water lubrication. Another example is cellulose acetate, the friction coefficients of which are identical when using either water or oil lubrication at high speeds. Under certain conditions, some Teflon-type plastics may also be unaffected by the change from water to oil lubrication. This result was not unexpected, in view of the extremely low friction coefficients of these materials. The addition of an oiliness agent, such as butyl stearate, to the test oil was found to make little or no difference in the frictional characteristics of the plastics tested.

### ● *BRAZING ALLOYS WITH LITHIUM ADDITIONS*

Industrial brazing practice shows that in numerous instances, as, for example, in the brazing of stainless steels, neither brazing with fluxes nor reducing atmospheres will yield completely satisfactory results. When brazing stainless steel with fluxes, the removal of fluxing compounds, especially in large pieces, may present difficulties. The comparative viscosity of fluxes saturated with metal oxides may inhibit the penetration of the

We extend to all readers our best wishes for a Happy Xmas and a Prosperous New Year

## let's STAY hot under the collar

Consider: through the walls of a one-foot length of uninsulated four-inch bore pipe, carrying steam at 500° F, you waste the heat produced by one ton of coal, every year! If this inefficiency gets *you* hot under the collar, how do you think your steam pipes feel—under their collars and flanges, round their bends and valves? If they're hot to you, you're wasting fuel by the ton. And that's where a little Fibreglass can save you a lot of money. In rigid sections, compact and lightweight, thickness for thickness, there's nothing in the world to beat it for efficiency. Moreover it is easily mitred to proof awkward corners against heat leaks. Other, even more difficult situations, and temperatures above 500° F and up to 900° F, are covered by Fibreglass in *flexible* sections.

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filler metal into joints with small clearances, producing joints of poor uniformity and strength. On the other hand, in a reducing atmosphere at a practical brazing temperature, stainless steel is subject to heavy oxidation if the atmosphere contains even the smallest amount of water vapour. It would therefore be of advantage to develop self-fluxing alloys including constituents capable of reducing the base metal oxides. By comparing some of the chemical and physical properties of lithium with the properties of some other strongly deoxidizing metals, it was found that lithium appears to be the most suitable metal for developing such alloys. Wettability tests performed with molten 1% lithium—99% silver alloy on low-carbon steel, drill rod, and stainless steel have confirmed this theoretical concept. Small additions of lithium not only reduce the oxides on the surfaces of these steels, but also considerably lower the wetting (contact) angle of molten silver, thus promoting wettability and fluidity. The lithium-bearing silver alloys and also lithium-bearing copper alloys should prove useful for brazing plain carbon steels, as well as stainless steel, without flux or reducing atmospheres. It is reported that the tensile strength of such joints is quite high.

● ***PREVENTION OF COPPER-TO-ALUMINIUM JOINT EMBRITTLEMENT***

The growing use of aluminium in the electrical and related industries has emphasized the importance of making reliable joints between aluminium and copper. One such method consists in flash-welding a short length of aluminium wire or tubing, as the case may be, to a corresponding short copper section and then making the conventional aluminium-to-aluminium and copper-to-copper joints at either end of the transition section. In the case of assemblies to be joined on site, this method enables the more difficult aluminium-to-copper joint to be made during the manufacturing process under closely controlled conditions, while the conventional copper-to-copper and aluminium-to-aluminium joints can be made in the field. Copper-to aluminium transition joints are known to stand up well at moderate temperatures, and such joints have remained ductile in service for many years, provided that the operating temperature did not exceed 80° C. However, when such joints were heated to 175° C or more, even for short periods, they became embrittled. This embrittlement is caused by the growth of intermetallic compounds at the joint. A recent investigation has shown that no embrittlement of the joint occurred when it was subjected for 500 days to temperatures up to 125°C, while embrittlement occurred in 24 hours or less at a temperature of 250° C; at 525° C the joint became embrittled in seconds. The effects of heating upon the growth of a diffusion layer consisting of intermetallic compounds are cumulative, and occasional overheating of the joint above the safe operating temperature will therefore lead to ultimate failure. It thus becomes important that the unavoidable diffusion layer produced in welding should be kept below a thickness at which it does not affect joint strength. It was found that the permissible thickness of the diffusion layer should not exceed 0·00004 in., and this is a result that can be obtained by the flash-welding process, owing to its self-cleaning nature.

● ***NEW DESIGN OF FREE-PISTON GAS GENERATOR***

The free-piston gas generator offers turbo-drive combined with diesel efficiency, but at the cost of increased thermal and mechanical loading. A recent invention promises substantial reductions in thermal and mechanical loading, without any corresponding increase in size or weight. The invention is dual, comprising a cycle and a mechanism. The essential feature of the cycle is single-stage compression in the diesel cylinder, combined with high-pressure bleed in the vicinity of the dead point. Such bleeding precedes combustion, which it may, or may not, overlap to some extent, and provides the turbo-drive. Initially, it is proposed to retain a large excess of air in the cylinder. The mechanism comprises a free-piston gas generator of large breathing capacity, in proportion to its size and for a given piston speed. It consists of two combustion spaces, between two co-axial pairs of opposed piston assemblies, with a large bore/stroke ratio. The inner pairs of pistons are fixed back to back, and the outer pair is tied together. These two assemblies are synchronized to oscillate in phase, so that compression takes place in one cylinder, while expansion takes place in the other. The mechanism and cycle together would appear to promise substantially reduced loading for a given size, output, and piston speed. Alternatively, the loading could be increased towards that of existing gas generators, e.g., by supercharging, with a correspondingly increased power output. The basic cycle efficiency is claimed to be slightly above that of the diesel engine, because the medium is expanded all the way down to atmospheric pressure.

● ***MAGNETIC BEARING FOR ELECTRIC METERS***

A novel type of magnetic bearing has been invented which is intended to be used for the vertical shaft of measuring instruments, especially of electric meters. It appears that earlier proposals of magnetic bearings for such purposes did not meet with success because of the irregularities of magnetic flux distribution across the surface of the bearings. Thus, the centering of the rotary parts was rendered difficult and bearing friction increased. The present invention envisages the

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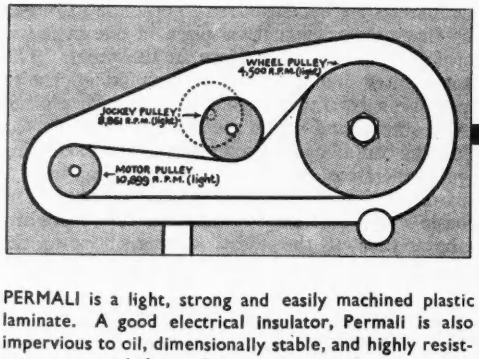


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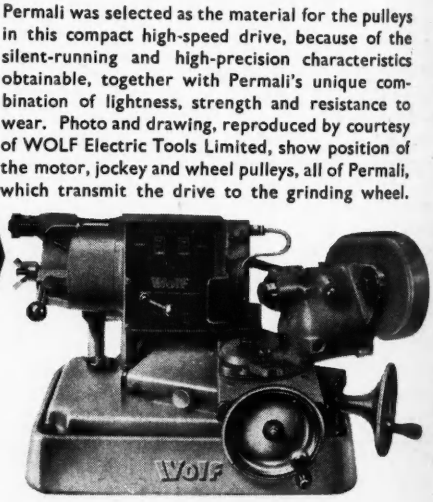


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use of an iron cone with a blunt apex at each end of the shaft, the shaft being arranged with small axial play between two permanent magnets fixed one above the other in the instrument. The upper magnet is made more powerful than the lower magnet, so that the upper end of the shaft is more strongly attracted. Both the upper and the lower magnets have ends in the shape of a cone with a blunt apex. Set in a spherical bearing in the apex of the upper cone of the shaft is a small ball which, by the preponderant magnetic pull of the upper magnet is pulled into a corresponding spherical bearing at the end of this upper magnet. The magnet systems are so adjusted that the ball is pulled against its upper stationary bearing in the upper magnet with a force of approximately one gram, this force being so small that no lubrication is required. The clearance between the lower tip of the shaft and the tip of the lower magnet is made approximately 0·05 mm. The magnetic field forces at this point are therefore strong enough to keep the shaft positively centered, without physical contact at its lower end.

● *NEW THERMOPLASTIC GUM MATERIALS*

By blending styrene-acrylonitrile resin and butadiene-acrylonitrile rubber, a new series of thermoplastic gum materials has been created which possess high flexural strength and stiffness, high hardness and toughness, good chemical resistance, and a high distortion temperature. It is stated that these materials can be extruded and injection- and transfer-moulded. Five types, with varying proportions of resin and rubber, have been developed, each designed for specific applications. The first type has maximum toughness and combines maximum impact strength with good chemical resistance and high heat resistance. This is the most difficult to be injection-moulded, except in the case of heavy-section parts, such as pipe fittings and valve bodies where large runners and gates can be used. Because of its higher acrylonitrile content, this material generally has the best chemical resistance of the series. The second material is a medium-impact material with the highest hardness and heat-distortion temperature of the series, and is intended for uses where these qualities are more important than impact strength. It has fair to good injection-moulding flow characteristics. The third material is a type with properties intermediate between the two previous types and is intended for more intricate moulded shapes where ease of flow is important. The fourth type is a straight-resin material with the maximum heat and chemical resistance of any material in the series. Finally, there is a special blend which combines toughness, rigidity, and good mouldability. It retains good toughness and high impact strength at temperatures as low as −40° F. With all five types liberal production tolerances are required to allow for thermal expansion.

● *PROLONGING THE LIFE OF CHROMEL-ALUMEL THERMOCOUPLES*

Chromel-Alumel thermocouples are quite stable in clean, oxidizing atmospheres such as normal atmospheric air. Good thermocouple practice requires the use of protection tubes in liquids, in corrosive gases, or under conditions where physical damage may occur. A good protection tube, closed at the exposed end, would be expected to safeguard thermocouple life under all conditions, but unfortunately this has not always been true. The most obvious trouble which may arise, and one of the most common, has been the presence inside the tube of residual foreign matter which becomes corrosive upon heating. The most common of these has been sulphur-bearing grease or oils. One recommended method of eliminating this trouble has been to burn out all tubes prior to use by soaking in a high-temperature furnace. A recent article points out that a more puzzling problem is the large error developed by a thermocouple when a protection tube which has been thoroughly burned out has too great a length-to-diameter ratio. Tests have shown the basic problem to be the preferential oxidation of the chromium constituent in the low-oxygen-pressure atmosphere produced in a closely confined tube. It has been definitely established that corrosion can be prevented by the exclusion or scavenging of all oxygen. Thus, when a titanium wire is inserted into a closed tube as an oxygen getter, there is little or no corrosion. In the case of open tubes the titanium definitely helps to use up the oxygen, but cannot keep up with the oxygen supply from the air. No indications are available as yet as to whether the getter can be entirely eliminated by thorough cleaning, evacuating, and sealing of the tubes.

● *HOLE SIZING BY MEANS OF CARBIDE BALLS*

It is claimed that considerable economy can be effected by giving holes in component parts their final size by pressing a carbide ball through the hole. In one particular instance, sizing was formerly done by honing but, by using a very simple press, the carbide-ball method produced the same result about five times as quickly. According to the report, on one type of job only two carbide balls were required over a two-year period, during which approximately one million holes in automotive gear-transmission shifter-fork forgings were sized. It is stated that the method is also used for sizing holes in steel-backed bronze bushings. Sizing by the carbide ball, however, slightly expands the metal and, if its thickness is not uniform, the hole will not be truly cylindrical. However, if the wall is of uniform thickness, true holes of excellent surface finish will be produced by this method. In the press designed for this operation, the operating stroke of the ram is upwards, and the carbide ball rests on top of the

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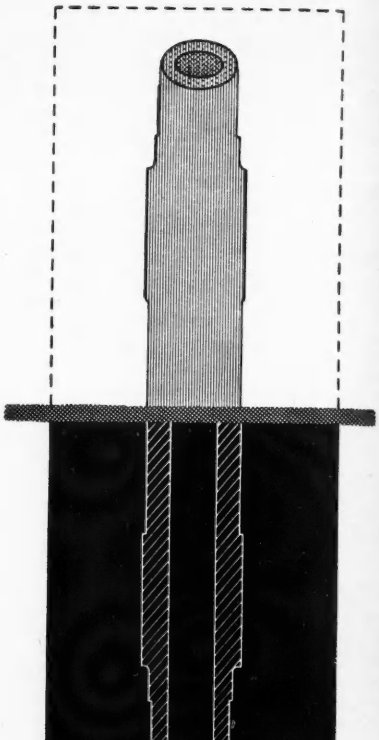

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ram inside a cylindrical guide at the centre of the press bed. The workpiece containing the hole to be sized is located with the hole roughly in line with the ram on top of the tubular ram guide. When the start-button is pressed, the ram moves upwards, forcing the ball into the hole, centering the latter precisely and pressing the workpiece against a tubular stop. As the ram continues upwards, the ball is pushed through the hole and into the upper tube, until it reaches a rear port, whereupon the ram stops. The ball, which has compressed a light side spring, is then ejected through the port and rolls into a curved return channel, through which it is passed back into the lower ram guide.

### ● *PRODUCTION OF POLYETHYLENE AT ATMOSPHERIC PRESSURE*

According to a recent announcement, a method has been found of producing polyethylene at atmospheric or even slightly lower pressure, whereas pressures as high as 2000 atm have hitherto been required. Moreover, in the new process, polyethylenes with molecular weights ranging from 10,000 to 2 million can be made, as compared with a maximum of 200,000 by the conventional method. It is claimed that the polyethylenes made by the new process possess superior mechanical and thermal properties, and the grades with high molecular weights exhibit approximately one-third the tensile strength of nylon. For press-moulding, the materials require to be heated to 170° C. It is considered that for general applications the grades with lower molecular weight are preferable because they do not require drastic alterations of the pressing tools. The production of polyethylene at atmospheric pressure has become possible by the employment of a new type of catalyst containing aluminium alkyls in combination with compounds of the No. IV, V, and VI groups of the periodic system. The catalyst finally chosen is a combination of aluminium triethyl and titanium tetrachloride, and causes the polymerization of ethylene at atmospheric pressure, when added in quantities of about 1%, in a highly exothermal reaction which is completed within a few hours.

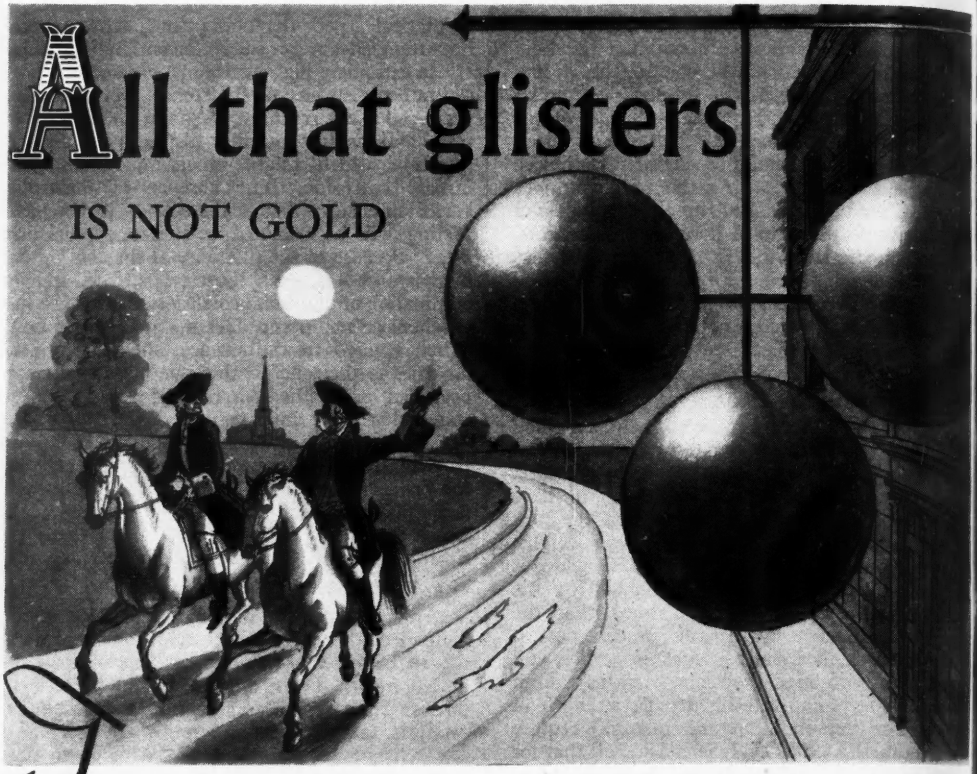
### ● *NEW RUST-PREVENTIVE PRIMER FOR STEEL*

A new and unusual type of primer for steel has been developed which is entirely different from ordinary paints and which is claimed to be especially effective in preventing the formation of rust on steel. It is stated that the new primer consists of a homogeneous, black colloidal precipitate which is thinned with a high-flash coal-tar solvent. While a conventional primer produces a rigid pigmented film, the new primer produces a plastic, gel-like coating. The nature of the precipitate used is not stated, but it is claimed to result from the chemical combination of certain ingredients, including lead. From the theoretical aspect the new primer offers several important advantages over conventional primers. It has extremely high wetting power and tends to saturate the surface of the steel. Since the film produced is not rigid but plastic, it tends to fill in pores and crevices and thus displaces any air and moisture which might otherwise remain and initiate corrosion. The absence of underfilm corrosion ensures that, if the coating is damaged, rusting will be confined to that one particular area. Because of the plasticity of the coating, its complete contact with the steel surface, and its elimination of underfilm corrosion, the coating has excellent adhesion and does not tend to peel off. When applied to the surface, the new primer air-dries to the touch within one hour, and a top coat can be applied shortly afterwards. It is stated that the primer can be applied by spray, brush, or dip, but spraying is claimed to be particularly easy, because of the homogeneity of the primer. When applied by brush, the primer is simply spread on, rather than " brushed out." Brush and spray units can be cleaned easily by rinsing in mineral spirits, turpentine, or naphtha.

### ● *FLUIDIZING CRUSHED COAL*

Application of the fluidizing technique to the high-speed discharge of fine coal from bunkers is reported to be now in an advanced stage of development. It is a well-known process to fluidize fine dry powders such as flour, cement, catalysts, etc., by passing air through them at a low velocity, so that they can be made to flow through pipes or along troughs under the influence of either static pressure or gravity. A technique is now being developed to apply the same principle to relatively coarse crushed coal with maximum sizes of about $\frac{3}{8}$ in. Prior to this investigation it was thought that the upper particle size limit for fluidization was about 100-mesh. The flow characteristics of crushed coal discharged from flat-bottomed tanks were investigated by studying the influence of moisture content and coal origin, using various particle sizes. The test reports state that promising results have been obtained. A great advantage of the aeration process will be the fact that it will permit a fuel storage tank to be filled to the top, without the usual cone extending from the chute into the tank. By aerating the tank while it is being filled, the surface of the crushed coal will rise like a liquid and remain horizontal until the tank is full. Thus, virtually the entire volume of a tank can be used for storing coal, and all the coal can be discharged, when required, except for the relatively small amount remaining, because of the final angle of repose of the coal. It is reported that the results of this investigation indicate that the aeration method has promise for application in industrial and public utility plants using small-size coal, as well as for locomotives.

# All that glisters IS NOT GOLD

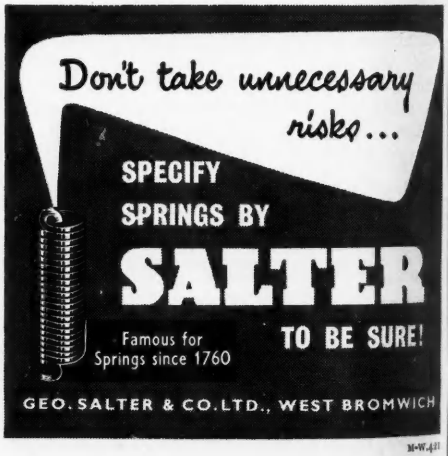


THREE GREAT golden balls glistened in the moonlight. "Zounds!" cried the First Robber—"there's as pretty a sight as ever I did see, all set out werry neat and orderly, and all a-ready for the taking of by two enterprising gents with an eye to business. Do you give me a leg, Skipper, and I'll part 'em from their moorings werry brisklike—afore ye can say Jack Ketch!"

"Tch!" murmured his companion, a man of sharper intellect and wider experience than honest Jeremy—"such simple faith is sadly misplaced, old friend. These globes are neither gold nor other precious metal, being wrought—probably in Birmingham—of brass. Hollow at that—" he added testily, rapping one of them with his cane. It gave out a dull, lack-lustre note.

Jeremy frowned. "Werry misleading and unethical," he muttered, "It's them sort of things from what man's ingratitood springs." He paused, pleasingly fuddled by his little rhyme.

"Speaking of springs," said the Captain darkly, and sounding suspiciously like an advertisement, "there's *another* bone of contention in this imperfect world. Did you know that the cheapest of springs may look every bit as good as the finest quality spring, specially designed and made for ultra-high performance? And, like the three golden balls, it's only when you come to try 'em out that you find you've been conducted up the garden path. Truly 'All that glisters is not gold'! Which reminds me, I really must redeem Lord Hartlebury's timepiece..."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